4.1.3.4.10.1.1 Worksurface Types

ESD protective worksurfaces used for FAA workstations shall meet the requirements of MIL-PRF-87893 Performance Specification, Workstation, Electrostatic Discharge Control and MIL-W-87893 Military Specification, Workstation, Electrostatic Discharge (ESD) Control.

4.1.3.4.10.1.2Type I Worksurface - Hard

Type I worksurfaces shall be constructed of rigid static dissipative materials of any color having an average Shore D hardness in excess of 90. Two male or female 0.395 inch ground snap (female) or stud (male) fasteners shall be installed on both corners on one of the longest sides of the worksurface to accommodate the male or female snap or stud fastener of the common point grounding cord. The locations of the two snaps or studs shall be 2 inches from each corner.

4.1.3.4.10.1.3Type II Worksurface - Soft

Type II worksurfaces shall be constructed of cushioned static dissipative materials of any color having an average Shore A (ATSM D2240) hardness in excess of 45 and less than 85. Two male or female 0.395 inch ground snap (female) or stud (male) fasteners shall be installed on both corners on one of the longest sides of the worksurface to accommodate the male or female snap or stud fastener of the common point grounding cord. The locations of the two male or female snaps or studs shall be 2 inches from each corner. No low-density open-cell materials shall be used for Type II worksurfaces.

4.1.3.4.10.2 Static Dissipative Laminates

High pressure, multi- layer static dissipative laminates shall be used to cover surfaces such as plywood, fiber board, particle board, bench tops, counter tops, and consoles in ESD controlled areas and special protection areas. Laminates shall include a buried conductive layer to provide for ease of grounding using a through bolted pressure type ESD grounding terminal.

4.1.3.4.10.3 Grounding of Laminated Surfaces

The resistance across the surface (R_{tt}) of the static dissipative laminate shall be greater.1.0 x 10^6ohms and less 1.0 x 10^9ohms. The resistance from the surface of the laminate to ground (R_{tg}) shall be greater than 1.0 x 10^6 ohms and less than 1.0 x 10^9 ohms (ANSI/ESD S4.1). A minimum of five readings of each shall be taken and averaged together. These readings and averages shall be recorded in the FRDF.

4.1.3.4.11 Static Dissipative Coatings

Permanent clear or colored static dissipative coatings used in ESD controlled areas, including all painted surfaces, shall have a point to point resistance greater than 1.0 x 10^6 ohms and less than 1.0 x 10^9 ohms.

4.1.4 Electromagnetic Compatibility Requirements

4.1.4.1 General

A comprehensive plan for the application of various sections of this document is required to assure the compatible operation of equipment in complex systems. Additional considerations of this section shall be implemented to reduce susceptibility and emissions of equipment.

4.1.4.2 Requirements
The emission and susceptibility limits contained in MIL-STD-461 shall be applied unless otherwise specified. An EMI Control and Test Plan shall be developed in accordance with MIL-HDBK-237 to assure compliance with the applicable requirements. The plan shall include a verification matrix to track the satisfaction of requirement by test, analysis or inspection. .

4.1.4.3 Approval
Control Plans and Test Plans shall be submitted to the OPR of this document for approval.

4.2 Facility Requirements

4.2.1 Passive Transient Protection Requirements
All metallic conduit, conductors and cables in NAS operational facilities are subject to currents induced by nearby lightning strikes. These induced effects can adversely affect the operation of sensitive electronic equipment.

4.2.1.1 Existing Metallic Conduit, Conductors and Cables
Unless the facility manager disapproves the removal, all unused conduits, conductors and cables shall be removed. The facility manager shall be consulted to validate the decision to remove any metallic conduit, conductors or cables prior to acting. If they are to remain, the following actions shall be accomplished to minimize the voltage differential between ends:

(a) Metallic conduits shall be bonded to adjacent grounded metalwork at both ends.
(b) Unused conductors bonded to adjacent grounded metalwork at both ends.
(c) Unused cables shall have conductors and shields bonded to adjacent grounded metalwork at both ends.

If not direct connected the above bonding shall utilize a 6AWG minimum pigtail no longer than 18 inches. Multiple conductors shall be grouped together and bonded to the adjacent metalwork directly or via a single pigtail.

Unused conductors of a structured cable system installed for spares purposes with vertical risers of no more than fifty feet and of circuit length totaling no more than three hundred feet are exempted from this requirement if they do not pass between facilities. Where circulating currents are present, installation of a SPD at one end of the cable shall be allowed for this requirement..

The OPR of this document should be contacted for additional information.

4.2.1.2 Electromagnetic Shielding for Lines, Conductors and Cables

4.2.1.2.1 Facility Entrance Conduit

All lines, conductors and cables, both overhead and buried, shall enter the facility through a minimum of 10 feet of ferrous conduit (RGS). Conduit routed by other than a direct route shall be allowed to achieve this 10-foot requirement. All entrance conduits shall be bonded to the EES with a bare copper stranded conductor, 2 AWG minimum. This entrance conduit, if buried, shall extend 5 feet beyond the earth electrode system.

4.2.1.2.2 Buried External Power Cables and Conductors

Buried external power cables and conductors shall have magnetic shielding to prevent coupling of damaging transient currents, from man made and lightning sources. This shielding can only be provided by a ferrous metal. This may be in the form of a sheath, ferrous armor or ferrous conduit (RGS). Specification details of this type of cable and potential sources are available from the OPR and the LPGBS web page. Ferrous armor cable has been shown to be extremely cost effective when compared to ferrous conduit and presents a marginal increase in cost over unarmored cable. Cables may be installed in metallic or nonmetallic conduit where permitted by the NEC. When a conduit is not used cables shall be identified for direct earth burial (DEB).

For portions of buried external power cables and conductors greater than 300 feet cable length from the facility ferrous shielding is recommended but not required. Facility entrance surge protection shall be provided that fully complies with paragraph 4.2.2 and all sub paragraphs.

4.2.1.2.3 Buried Landlines

The preferred type of buried landline that represents best engineering practice is fiber optic type. Fiber optic cable does not require electromagnetic shielding and is exempt from these requirements. Metallic buried landlines that carry NAS Critical, Essential or Mission Support Services to a facility shall have a ferrous shield or be enclosed in ferrous conduit (RGS).

For portions of these buried landlines located greater than 300 feet cable length from the facility, ferrous shielding is recommended but not required. For these landlines facility entrance surge protection shall be provided that fully complies with paragraph 4.2.2 and all sub paragraphs.

4.2.1.2.4 Conduit Joints and Fittings

Conduit joints and fittings shall be electrically continuous with bonding resistance of 5 milliohms or less between joined parts. Conduit enclosing signal, control, status, power, or other conductors to electronic equipment shall be terminated using conductive fittings to their respective junction boxes, equipment cabinets, enclosures, or other grounded metal structures.

4.2.1.3 Above Ground Ferrous Conduit Penetration of Facility

At each location, where above ground conduits first penetrate a shelter or building a bonding connection shall be made. The conduit shall be bonded directly to the EES, or to a bulkhead connector plate that is bonded to the EES in accordance with paragraph 4.2.1.6. If neither of these bonds is feasible, the bond shall be made to the main or supplemental ground plate. The bond to the EES, or the bulkhead connector plate, or to the multipoint ground plate shall be a 2 AWG stranded copper conductor using exothermic welds or UL listed pressure connectors.

4.2.1.4 Armored Direct Earth Burial (DEB) Cables

The DEB cable armor shall be bonded to the EES with a 2 AWG conductor prior to entry into the conduit. The DEB cable armor shall also be bonded to the main or supplemental ground plate. If bonding to the main or supplemental ground plates is not feasible the armor shall be bonded to the ground bus at the service disconnecting means (SDM). If armor is continued to the electronic equipment, bond it to any SRS – except to a single point ground system – of the electronic equipment unless the equipment is required to be isolated. All bonds shall be less than 5 milliohms between joined parts. Apply this requirement during initial cable installation. Complete cable replacement is not required if only a short length requires repair.

4.2.1.5 Guard Wires

A 1/0 AWG bare copper stranded guard wire shall be provided for all buried cables and conductors not routed in ferrous conduit. The guard wire shall be embedded in the soil, a minimum of 10 inches (25 cm) above the cable to be protected and located directly above and parallel to the lines or cables being protected. When the width of the cable run or duct does not exceed 3 ft (90 cm), one guard wire, centered over the cable run or duct, shall be installed. When the cable run or duct is more than 3 feet (90 cm) in width, two guard wires shall be installed. The guard wires shall be spaced at least 12 inches (30 cm) apart and be not less than 12 inches (30 cm) nor more than 18 inches (45 cm) inside the outermost wires or the edges of the duct. The guard wire shall be bonded to the EES at each end and to ground rods at approximately 90-foot intervals using exothermic welds. The spacing between ground rods must vary by 10% to 20% to prevent resonance. Install the ground rods at approximately 6 feet (2 m) on either side of the trench. Where cables run parallel to the edge of a runway, they shall be located 10 feet from the edge lights on the outside of the lights.

4.2.1.6 Metal Bulkhead Connector Plates

A metal bulkhead connector plate shall be provided where overhead axial-type cables, waveguides, etc., first enter a facility. The bulkhead connector plate shall be mounted on the outside surface of the facility, a minimum of $^1/_4$ inch thick, and shall be constructed of tin-plated copper. The plate or plates shall have the required number and types of feed-through connectors to terminate all axial cables and shall provide adequate surface area for bonding waveguides, cable shields, conduits etc. Cable shields shall be bonded and grounded, except when the shield must be isolated for proper equipment operation. If external and internal cables are of different sizes, the changeover in cable size shall be allowed by the feed-through connectors at the plate.

Axial type cables, Waveguides, etc.(and conduits where not bonded directly to the EES) shall be bonded to the bulkhead plates with a minimum 4 AWG bonding jumper. The 4 AWG bonding cable for a waveguide can be connected to the waveguide flange with an appropriately sized ring terminal. Conduits shall be bonded with a UL listed U-Bolt bonding connector. Axial cable shields shall be bonded with bonding kits sized for the specific cable type. Bonding jumpers shall be connected to the plate with either an exothermic weld or a double-bolted lug and shall be no longer than 12 inches.

The bulkhead plate shall be bonded to the EES with a minimum 4/0 AWG copper cable color-coded green with a red tracer. When the bulkhead connector plate is located within 6 feet of building steel, the bulkhead plate shall be connected to building steel with a 4/0 AWG copper conductor color coded green with a red tracer. The building structural steel is required to be bonded to the EES. Exothermic welds shall be used for these connections.

4.2.1.7 Balanced Pair Lines

When possible, signal and control circuits routed external to equipment shall be balanced, two conductor, shielded circuits.

4.2.1.8 Fiber Optic Cable

Fiber optic cables are not inherently susceptible to electromagnetic interference or the induction fields produced by lightning. Fiber optic cables should replace metallic cables when economically and technically feasible. Ferrous conduit shielding is not required for fiber optic lines. Suppression components are not required for fiber optic cables. Where metallic or electrically conductive sheaths or strength members are present, they shall be grounded to any SRS – except to a single point ground system at each end. To prevent circulating ground currents, a SPD shall be allowed at one end for grounding. The fiber optic transmitter and receiver modules shall have 90 dB of attenuation against all sources of electromagnetic interference (EMI).

Where an external fiber optic cable uses conductive armor, the armor shall be bonded directly or via a SPD to the EES at the facility entrance using a 2 AWG bare copper conductor. If the cable is internal to the facility, conductive armor shall be bonded to any SRS – except to a single point ground system – at the equipment entrance. The bonding conductor shall be a 4 AWG stranded copper conductor insulated green with an orange tracer. The use of fiber optic cables without a conductive shield or armor is permitted. The fiber optic transmitter and receiver modules shall be contained in ferrous enclosures bonded to the nearest SRS – except to a single point ground system. Penetrations of the enclosures shall be gasketed or constructed to limit RF coupling. SPD's for the metallic signal circuits and power circuits shall be installed as equipment level protection at the fiber optic receiver or transmitter equipment entrance and bonded to the chassis.

4.2.1.9 Interior Lines, Conductors and Cables

All permanently installed single conductors, cables and wiring shall be in ferrous conduit (RGS), ferrous intermediate metal conduit (IMC), ferrous electrical metallic tubing (EMT), ferrous cable trays, or ferrous wireways (except as prohibited by the NEC). These shall be connected to any SRS – except to a single point ground system – as specified in paragraphs 4.2.6.4.1 and 4.2.6.4.2.

When routing between floors the vertical section of the runs shall be in ferrous conduit (RGS), ferrous IMC, ferrous EMT, enclosed ferrous cable trays, or ferrous wireways that are connected to any SRS – except to a single point ground system – as specified in paragraphs 4.2.6.4.1 and 4.2.6.4.2.

Cable tray systems employing single rail or wire construction are prohibited at any location.

4.2.2 Active Transient Protection Requirements

4.2.2.1 Conducted Power Line Surges

Surge protective devices (SPDs) shall be provided at the service disconnecting means (SDM), at all facility penetrations (entrances), and at feeder and branch panelboards as specified in paragraph 4.2.2.3. Additional SPDs shall be provided at the power line entrances to operational electronic equipment. SPDs at the service disconnecting means, facility penetrations (entrances), feeder and branch panelboards as well as transient suppression provided at electronic equipment power line entrances shall be coordinated in accordance with the guidance provided in paragraphs 4.2.2.2 and 4.2.2.3.

4.2.2.2 Facility Entrance Surge Protective Devices

A facility power SPD shall be installed on the load side of the facility service disconnecting means, at any facility penetration (entrance) and between the load side of a Engine Generator transfer switch and the first feeder panel.

The SPD shall be a combination of solid-state circuits, varistors, or other devices and shall meet the requirements provided in this paragraph and its subparagraphs. Protection will be provided between all lines, including neutral where provided, and ground. A surge arrestor shall also be installed on the primary side of FAA owned distribution transformers. These arresters and SPDs shall be approved by the OPR of this document.

The SPD shall be installed as close as possible (within 12 inches) to the facility SDM and with the shortest and most direct conductor connection to the SDM. Connections shall be made with UL listed connectors identified for the wire size and type used.

(a) Connections. SPD terminals shall be connected to corresponding terminals of the service disconnecting means with insulated 2 AWG (minimum) copper conductors. The conductors shall be as short and direct as possible without loops, sharp bends or kinks, be all the same size, and be color-coded in accordance with FAA-C-1217. The ground bus in the service entrance enclosure shall be bonded directly to the SPD terminal marked G or ground. The SPD enclosure shall be bonded to the SPD ground terminal.
(b) Conduit sealing. The conduit connecting the SPD enclosure to the SDM enclosure shall be sealed with duct seal or other UL listed nonflammable medium to prevent soot from entering the SDM enclosure in the event of SPD failure.

4.2.2.3 Surge Protective Devices for Feeder and Branch Panels

SPDs shall be installed on all panels providing service to NAS operational equipment or supplying exterior circuits. Examples of exterior circuits include obstruction lights, convenience outlets, guard shacks, security systems, electric gates and feeds to other facilities. Exterior circuits shall be protected in accordance with the requirements of paragraph 4.2.2.2. Where feeder and branch panels are located close together and the panels do not serve exterior circuits, the OPR of this document shall be allowed to grant relief from providing separate protection on each panel. SPD's for panels that provide service to any exterior circuits shall meet the requirements given by paragraphs 4.2.2.4.2, 4.2.2.4.3, and 4.2.2.4.4 for facility entrance SPD's. The SPD's shall be installed as close as possible to the panel they serve and in accordance with the manufacturer's instructions. The conduit connecting the SPD enclosure to the panel enclosure shall be sealed with duct seal or other UL listed nonflammable medium to prevent soot from entering the enclosure in the event of SPD failure. A feeder or branch panel SPD shall be provided with an overcurrent device. Examples of this overcurrent device include a fuse or circuit breaker fitted internally to the SPD or fitted to the panelboard for the sole use of the SPD. The overcurrent device shall not increase the clamp voltage of the SPD by greater than 5% and shall pass the surge current levels listed in Table IV up to the 40kA level without opening. Overcurrent devices for any exterior circuits shall pass all values shown in Table IV. All overcurrent devices, both internal and external to the SPD, and SPD short circuit current ratings shall be properly sized and coordinated in accordance with the NEC and be field resettable or replaceable.

4.2.2.4 SPD General Requirements

SPDs shall be listed in accordance with UL 1449 Second Edition. All components comprising a SPD shall be packaged in a single National Electrical Manufacturers Association (NEMA) type 12 steel enclosure for indoor use only, or a NEMA type 4 steel enclosure for indoor or outdoor use. SPDs enclosed within panelboards or switchgear enclosures shall be allowed, provided the integrated SPD and panelboard or switchgear is UL listed/recognized as components and as an assembly. The use of potting material in SPDs is strictly prohibited. All SPD components must be accessible for inspection by qualified FAA personnel. Heavy duty, screw-type studs shall be provided for all input and output connections. The SPD phase and neutral terminals, when not connected, shall be electrically isolated from the enclosure by a minimum of 10 megohms resistance measured at 100V DC. The enclosure door shall be hinged and electrically bonded with a bonding jumper to the enclosure. Fuses, lights, fuse wires, and arrester elements or components shall be readily accessible for inspection and replacement. Manufacturers shall supply clear installation instructions with each unit.

4.2.2.4.1 SPD Operational Characteristics

Minimum functional and operational characteristics of SPDs are given in Table IV, Table V, and Table VI. Other characteristics will also include the following:

(a) Maximum continuous operating voltage (MCOV). The maximum continuous operating voltage is the maximum RMS voltage an SPD will withstand at its maximum operating temperature continuously without degradation or change to any of its parameters greater than +/- 10%. The MCOV shall not be less than 10 percent above the nominal system voltage. Leakage current as defined below shall not be exceeded.

(b) Leakage current. The DC leakage current shall be less than 1mA for voltages at or below 1.414 x MCOV VDC.

(c) Clamp (discharge) voltage. Clamp (discharge) voltage is the maximum voltage that appears across an SPD output terminal while conducting surge currents. This voltage, measured at 3kA (to ensure performance in the linear region without impacting the device lifetime performance) with an 8/20 microsecond waveform, shall not change more than 10 percent over the operating life (as defined in Table IV. Surge Current Lifetime Requirements) of the SPD.

(d) Overshoot voltage. Overshoot voltage shall not exceed twice the SPD clamp voltage for more than 10 nanoseconds. Overshoot voltage is the surge voltage level that appears across the SPD terminals before the device turns on and clamps the surge to the specified voltage level.

(e) Self-restoring capability. The SPD shall automatically return to an off state after surge dissipation when line voltage returns to normal.
(f) Operating lifetime. The SPD shall safely dissipate the number and amplitude of surges listed in Table IV. Surge Current Lifetime Requirements.
(g) In-line inductors. In-line inductance, other than that normally caused by routing conductors, is not permitted.
(h) Fusing. Any fuses part of a SPD installation shall be able to pass all surge currents specified in Table IV without opening.

4.2.2.4.2 Surge Levels

Table IV defines line-to-ground, line-to-neutral, neutral to ground, and line-to-line surge currents, and number of occurrences for AC services in FAA facilities below 600V. In this table, the 8/20 μs wave form defines a transient reaching peak value in 8 μs and decays to 50 percent of peak value 20 μs after inception. These devices shall be able to tolerate surges of shorter duration without malfunction.

Table IV. Surge Current Lifetime Requirements

Surge Current Amplitude 8/20μs Waveform	Surge Number Lifetime Any Facility Entrance	Surge Number Lifetime Feeder and Branch Panels
10kA	1500	1000
20kA	700	500
30kA	375	250
40kA	50	25
50kA	8	1
60kA	6	
70kA	4	
100kA	2	
200kA	1	

Each level of surge current and the number required represents a single lifetime of an SPD.

(a) Any change greater than 10% in the 8/20μs clamping voltage at 3kA during service or when the pre life/service test and the post life or in-service test results are compared is a device failure. The pre life test value shall be taken as the 100% value.
(b) Any change greater than 10% in the RMS voltage required to drive 1mA RMS through the device when the pre life/service test and the post life or in-service test results are compared is a device failure. The pre life test value will be taken as the 100% value.
(c) Any change greater than 10% in the DC voltage required to drive 1mA DC through the device when the pre life/service test and the post life or in-service test results are compared is a device failure. The pre life test value will be taken as the 100% value.
(d) Clamping voltages for each of the devices/assemblies/system voltages will be measured at 1kA and 10kA 8/20μs.

4.2.2.4.3 Slope Resistance

It is the purpose of this parameter to specify a region on the SPD characteristic where it is possible to ensure device coordination. A slope resistance (the slope of the voltage/current characteristic of an SPD in its linear region) shall be calculated from the formula below:

$R_{slope} = (V_{10}\text{-}V_1)/9000$

Where V_{10} = the clamping voltage measured at 10kA 8/20μs

and

Where V_1 = the clamping voltage measured at 1kA 8/20μs

The values of V_{10} and V_1 used will be the absolute values as measured and not as a calculated value. The slope values shall conform to Table V.

Table V. Entrance, Feeder, and Branch Panels Slope Resistance Requirements

Location	Slope Resistance
Any Facility Entrance	8 mΩ Maximum
Feeder and Branch Panels	30 mΩ +/- 15 mΩ

4.2.2.4.4 3kA Voltages V_3

The voltages that must be achieved during testing at 3kA with an 8/20μs current impulse is shown in Table VI. All voltages shall be measured at the device terminals. The 8/20μs current impulse wave shape shall not lead or lag the voltage wave shape by more than 30 degrees.

Table VI. Protection Voltages at 3kA

Location	System	V_3	Limit
Any Facility Entrance	120/208V 120/240V	400 L-N, L-G 700 L-L	Maximum
Any Facility Entrance	277/480V	700 L-L, L-G	Maximum
Any Facility Entrance	380V Delta	1200 L-L,L-G	Maximum
Any Facility Entrance	480V Delta	1200 L-L, L-G	Maximum
Feeder and Branch panels	120/208V 120/240V	475 L-N, L-G 775 L-L	+/- 45V
Feeder and Branch panels	277/480V	775 L-N, L-G 1275 L-L	+/- 45V
Feeder and Branch panels	380V Delta	1275 L-L, L-G	+/- 45V
Feeder and Branch panels	480V Delta	1275 L-L, L-G	+/- 45V

4.2.2.4.5 Indicator Lamps

Indicator lamps shall be provided for each phase on the SPD enclosure cover. They shall visually indicate normal condition (power applied to the SPD with any component fuses intact).

If indicator lamps are used that have a service life of less than 50,000 hours then two lamps per phase shall be provided.

4.2.2.4.6 Accessibility

All SPD installations shall be safely accessible for visual inspection and evaluation. The use of potting material or other encapsulating materials that prevent component inspection in SPDs shall be limited to inorganic particulates. All SPD components shall be accessible for maintenance and replacement by qualified FAA personnel. Determination of the acceptability of potting material or other encapsulating materials in a given design resides with the OPR of this document.

4.2.2.5 Signal, Control, and Data Line Protection Design

Transient protection shall be provided for all signal, data and control lines; both at facility entrances and at entrances to all electronic equipment used in direct support of the NAS including those provided or installed by a telecommunications service provider.

The suppression components at the facility and electronic equipment entrances shall be coordinated to function together and limit the transient voltage and energy safely below circuit susceptibility levels. Coordination of suppression components is dependant on several factors including separation distance, equipment system bandwidth, etc. In principle facility entrance devices and electronic equipment entrance devices shall not affect each others operation. The coordination of these protectors is achieved at the system design stage – not intended to be accomplished by field personnel (see paragraph 4.3.2).

Detailed analyses of suppression component and electronic equipment circuit characteristics are required to select components compatible with the requirements herein and to provide suppression circuits that will function without adversely affecting signals and information transmitted by individual landlines. Design requirements for selection of components are as follows:

(a) Unipolar suppression components shall be selected and installed for signals and voltages that are always positive or always negative relative to reference ground. Bipolar suppression components shall be selected for signals and voltages that are both positive and negative relative to reference ground.
(b) The total series impedance of the suppression circuits at both ends of a landline shall be designed so as not to significantly degrade electronic equipment performance.
(c) The protection components at facility entrances and equipment shall be selected so that their operating levels are coordinated and transient levels to equipment are limited safely below electronic equipment susceptibility levels for individual lines.

Surge protective devices shall be placed on both ends of signal, data and control lines longer than 10 feet connecting pieces of equipment or facilities not located on and bonded to the same SRS, or when the SRGG, SRGP, and the multipoint ground system is located in different rooms or on different floors. This includes all signal, data, control, and status lines both internal and external. This also includes interfacility lines installed above and below grade between facility structures and to externally mounted electronic equipment and particularly vertically routed conductors and cables such as those between an ATCT cab and base building or radar tower and base building. This requirement includes fire alarm and security wiring where it has direct impact on NAS equipment.

All unused conductors of a cable shall be grounded at each end. Grounding through an SPD is permissible if grounding both ends of the conductors degrades system performance.

4.2.2.6 SPD Requirements for Signal Data and Control Lines

Facility level SPDs for signal, data, and control lines shall be installed at the point where the lines transfer to FAA control and at any building/structure entrance under FAA control. Where a battery feeds signal, data or control lines, the suppression components shall be housed in a metal enclosure. For facility level SPD enclosures, a ground bus bar, electrically isolated from the enclosure, shall be provided to serve as the ground point. This ground bus bar shall be directly connected to the EES with an insulated 4 AWG or larger copper conductor of minimum length with no loops, sharp bends or kinks, and ensure a short direct path for connection to the SPD's. NOTE: When at the top of a tall ATCT (greater than 100 feet) the main ground plate on the lowest level containing NAS electronic equipment serves in lieu of the EES. The conductor insulation shall be color-coded green with a red tracer. A UL listed double bolted lug shall be used to bond the conductor to the ground bus bar. The bonding to the EES shall be an exothermic weld. The ground bus bar location shall ensure a short, direct path to ground for SPD's. The installation shall provide easy access to component terminals for visual inspection, test and replacement.

SPD's for landlines that combine the protection specified herein shall be located at the facility entrance, and have approval by the OPR of this document prior to implementation of vendor proposed protection. (Reference paragraph 4.2.2.5)

Field designed protection schemes shall be submitted to the OPR of this document for guidance and approval.

Transient suppression components for axial-type cables shall be packaged in a sealed metal enclosure with appropriate connectors at each end to permit in-line installation at the bulkhead connector plate required in paragraph 4.2.1.6.

4.2.2.6.1 Signal, Control, and Data Line Protection Requirements

The 10/1000 μs waveform defines a transient with a 10μs rise time and decay to 50 percent of the peak voltage in 1000 μs. SPDs must survive the transients listed in Table VII. Failure or end of life performance of a protector shall not normally disrupt the operation of the circuit being protected.

Table VII. SPD Lifetime Conducted Landline Transient Level Requirements

Lifetime Number of Transients	Transient Levels	
1,000	100V	50A
500	500V	100A
50	750V	375A
5	1000V	1000A

Each level of surge current and the number required represents a single lifetime of an SPD.

4.2.2.7 Axial Cable Protection Design

Special attention shall be given to the design of transient protection for axial-type cables. Design of transient protection is particularly critical at RF frequencies due to insertion losses. The following design requirements apply:

(a) Analyses and tests shall be performed to assure that suppression components do not degrade signals to an unacceptable degree or cause marginal performance of electronic equipment.
(b) Particular attention shall be given to the impedance, insertion loss, phase distortion, and voltage standing wave ratio for RF signals.
(c) Transient protection for electronic equipment using coaxial, tri-axial, and twin-axial cables shall be provided both at facility entrances and at the electronic equipment.

Transient suppression shall be provided for each axial conductor and for shields that are not bonded directly to the electronic equipment case.

4.2.3 Lightning Protection System Requirements

4.2.3.1 General

The intended purpose of the lightning protection system is to provide preferred paths for lightning discharges to enter or leave the earth without causing facility damage or injury to personnel or equipment. The essential components of a lightning protection system are air terminals, roof and down conductors connecting to the EES, the EES and SPDs. These components act together as a system to dissipate lightning energy. The lightning protection system shall meet or exceed the requirements of all relevant FAA standards and orders; Standard for the Installation of Lightning Protection Systems, National Fire Protection Association (NFPA 780); Installation Requirements for Lightning Protection Systems, Underwriters Laboratories (UL 96A); and, as specified herein. The risk assessment guide in NFPA 780 indicates that many NAS facilities have a high risk index. Accordingly lightning protection that exceeds the minimum requirement of NFPA 780 is specified. The provision of a UL Master label is not sufficient to indicate compliance with this document.

4.2.3.2 Lightning Protection System Materials

All equipment shall be UL listed for lightning protection purposes and marked in accordance with UL requirements. All equipment shall be new and of a design and construction to suit the application in accordance with UL 96A requirements, except that aluminum shall only be used on aluminum roofs, aluminum siding or other aluminum surfaces. Bimetallic connectors shall be used for interconnecting copper and aluminum conductors. Dissimilar materials shall conform to the bonding requirements of paragraph 4.1.1.2.3.

4.2.3.2.1 Lightning Protection System Conductors

All conductors used in a lightning protection system (main and bonding) shall be class 2 main sized conductors as defined by NFPA 780 or larger.

4.2.3.2.2 Lightning Protection System Hardware

4.2.3.2.2.1 Fasteners

Roof and down conductors shall be fastened at intervals not exceeding 3 feet (0.9 m). Fasteners shall be of the same material as the conductor base material or bracket being fastened, or other equally corrosion resistant material. Plastic, galvanized or plated materials shall not be used. Where fasteners are used for bonding the surface shall be prepared and protected in accordance with paragraphs 4.1.1.7 and 4.1.1.8.

4.2.3.2.2.2 Fittings

Bonding devices, conductor splices, conductor attachments and connectors shall be suitable for use with the installed conductor and shall be stainless steel, copper, bronze, or aluminum with bolt pressure connections to the conductor. Crimp type fittings shall not be used anywhere for any purpose in the lightning protection system. Aluminum fittings shall only be used with aluminum conductors. Copper and bronze fittings shall only be used with copper conductors. Interconnection between copper and aluminum portions of the lightning protection system shall be accomplished with bimetallic connectors.

4.2.3.2.3 Guards

Guards shall be provided for down conductors located in or next to driveways, walkways or other areas where they are at risk of being displaced or damaged. Guards shall extend at least 6 feet (1.8 m) above and 1 foot (0.3 m) below grade level. Guards shall be schedule 40 polyvinyl chloride (PVC) conduit or better. When metal guards are used, the guard shall be bonded to the down conductor at both ends of the guard. Bonding jumpers shall be of the same size as the down conductor. PVC guards do not require bonding.

4.2.3.3 Lightning Protection System Bonds

4.2.3.3.1 Metallic Bodies Subject to Direct Lightning Strikes

Metallic bodies that protrude beyond the zone of protection provided by the installed air terminals, are subject to direct lightning strikes. This includes, but is not limited to, exhaust pipes, exhaust fans, metal cooling towers, HVAC units, ladders, railings, antennas, and large louvered structures, etc. When these metallic bodies have a metal thickness of $^{3}/_{16}$ inch or greater, they shall be bonded to the nearest main lightning protection system conductor. These fittings shall provide bonding surfaces of not less than 3 square inches. If the metal parts of these units are less than $^{3}/_{16}$ inch thick, additional air terminals, main conductors and fittings shall be installed, providing two paths to ground from the air terminals.

4.2.3.3.2 Metallic Bodies Subject to Induced Charges
Metallic bodies that are subject to induced charges from lightning (including those in a zone of protection) shall be bonded to the lightning protection system in accordance with the guidance provided in NFPA 780. This includes, but is not limited to, roof drains, vents, coping, flashing, gutters, downspouts, doors, door and window frames, balcony railing, conduits, pipes, etc.

4.2.3.3.3 Exhaust Stack Grounding.
Bond all fossil fuel exhaust stacks to the nearest point in the lightning protection system or directly to the EES with a conductor of equal size as the main conductor. The bond to the exhaust stacks shall be made with an exothermic weld or a mechanical connector. Where exhaust stacks are not in close proximity (6 feet) to a main conductor, they shall be bonded directly to a ground rod in the EES.

4.2.3.3.4 Above Ground Fuel and Oil Storage Tanks.
Lightning protection shall be provided for all above-ground fuel and oil storage tanks. An air terminal shall be mounted to the top of non-pressurized fuel and oil tank vent pipes, high enough to provide the required zone of protection for the entire tank, and be connected directly to the EES using a main-sized down conductor.

Tanks shall be provided with at least two easily accessible, widely separated grounding points. Each of these grounding points shall be bonded directly to the EES. All other metallic components, e.g., stairs and skids, shall be bonded with 4/0 AWG copper conductors or if 4/0 AWG is not feasible then the largest feasible conductors. These conductors shall be exothermically welded to the EES.

Pressurized fuel tanks (propane, compressed natural gas, etc.) shall be bonded directly to the EES at one of the support legs.

4.2.3.4 Conductor Routing
Down conductors shall follow the most direct downward course. Main and bonding conductors must maintain a downward or horizontal course, and are permitted to rise at no greater than ¼ pitch.

No bend in a main and bonding conductor shall form an included angle of less than 90 degrees, nor shall it have a bend radius (sweep) of less than 8 inches. Connections between crossing conductors will use sweeps in all directions. T-connectors shall be allowed only for mechanical support.

Conductors shall be routed outside of any structure and not penetrate or invade that structure (except as indicated below in paragraph 4.2.3.6). Conductors shall be routed 6 feet or more from power or signal conductors in air or through walls. If this clearance cannot be met, the power and signal conductors shall be routed in ferrous conduit (RGS) or enclosed ferrous cable tray.

Conductors shall be allowed to pass through a parapet, eave, walkway, wall, etc., where necessary to maintain horizontal or downward course of main conductors. Pass-throughs shall always be accomplished using main conductors, routed through Trade Size 2, Schedule 80, rigid PVC conduit. When a conductor penetrates a metallic structure of any thickness, the conductor shall be bonded to the metallic structure. Conductors passing through gratings or plates do not require conduit but do require bonding.

4.2.3.4.1 Down Conductors on Fiberglass Mounting Poles

Where a fiberglass pole is used to mount an air terminal, the air terminal shall extend two feet above the top of the pole and shall be securely fastened to the pole in accordance with the requirements of NFPA 780. The down conductor from the air terminal shall be run on the exterior of the fiberglass pole and shall be fastened to the pole at intervals not exceeding 3 feet. This down conductor shall be connected to the EES in accordance with paragraph 4.2.3.4.2.

4.2.3.4.2 Down Conductor Terminations

Down conductors shall be exothermically welded to a 4/0 AWG copper conductor prior to entering the ground at not less than 18 inches above the ground level. The 4/0 AWG copper conductor shall enter the ground and be welded to a ground rod that is exothermically welded to the EES.

4.2.3.5 Lightning Protection for Buildings and Structures

Lightning protection shall be provided for all buildings and structures, or parts thereof, not within a zone of protection provided by another building or higher part of a building, or by an antenna or tower. Zones of protection for all structures shall be as defined in NFPA 780.

4.2.3.5.1 Air Terminals

Air terminals shall be solid copper, bronze, or aluminum. In areas of high corrosion, air terminals shall be stainless steel. Copper air terminals shall be allowed to have nickel-plating. Air terminals shall be a minimum of 12 inches in height, at least $^1/_2$ inch in diameter for copper and at least $^5/_8$ inch in diameter for aluminum. Air terminals shall be located and installed in accordance with the requirements of NFPA 780 and UL 96A, and as required by this document. Closer spacing shall be allowed for unique geometries. Air terminals shall extend at least 10 inches above the object or area it is to protect. Air terminals shall be placed on the ridges of pitched roofs and around the perimeter of flat or gently sloping roofs at intervals not exceeding 20 feet except that air terminals 24 inches or higher shall be allowed at intervals not exceeding 25 feet.

SAFETY NOTE:

The tip of vertical air terminals shall not be less than 5 feet above adjacent walking or working surfaces to avoid the risk of personnel injury.

4.2.3.5.2 ATCT Potential Equalization

A continuous potential equalization loop (halo ring) shall be installed on the roof or roof parapet, within 24 inches of the periphery of the structure. All air terminals and down conductors shall be connected to this loop. Any parts of the structure below the roof level that extend outboard of the potential equalization loop shall be provided with additional air terminals at the extremities of the structure.

Potential equalization loops shall be installed at intermediate levels, evenly spaced no more than 60 feet apart, measured from the roof loop. Additional horizontal air terminals will be installed at each potential equalization loop.

All exterior catwalks and personnel access areas shall be provided with a potential equalization loop interconnected to the down conductors. Horizontal air terminals shall be installed at each corner.

4.2.3.5.3 Number of Down Conductors for Buildings

The number of down conductors shall be based of both the building height and perimeter. For the purpose of this paragraph, an ATCT with a base building shall be treated as two separate buildings.

Buildings and structures less than 50 feet high (measured to the highest point of the building or structure) shall have at least two down conductors. Buildings and structures more than 50 feet and less than 100 feet high shall have at least four down conductors. Buildings and structures more than 100 feet high, other than antenna towers, shall have one additional down conductor for each 50 feet of height or part thereof, e.g., a 150 foot building would have a minimum of five down conductors, a 300 foot building would have a minimum of eight down conductors, etc.

Buildings and structures with perimeters in excess of 250 feet shall have an additional down conductor for each 100 feet of perimeter distance or part thereof. Down conductors shall be as widely separated as possible, e.g., at diagonally opposite corners on square or rectangular buildings. The down conductors shall be equally spaced and without any sharp bends, or kinks. Building steel, metal supporting structures, and conduits shall not be used in place of down conductors.

4.2.3.5.4 Metal Parts of Buildings

Metal roofing, structural and reinforcing steel, siding, eave troughs, down spouts, ladders, duct, and similar metal parts shall not be used as substitutes for roof or down conductors. A lightning protection system shall be applied to the metal roof and to the metal siding of a metal clad building in the same manner as on a building without metal covering. Building metal parts shall be bonded in accordance with paragraph 4.2.3.3.

4.2.3.5.5 Roof Mounted Antenna Masts

Unless it is a radiating or receiving part of the antenna, a metallic mast of a roof-mounted antenna shall be bonded to the nearest roof or down conductor. If a roof or down conductor is not available then the antenna mast shall be bonded directly to the EES.

4.2.3.6 Lightning Protection for Antenna Towers

4.2.3.6.1 Number of Down Conductors for Towers

Towers that consist of multiple, parallel segments or legs that sit on a single pad or footing not over nine square feet in area are also considered pole type towers. All other towers shall have at least two down conductors. Large towers, such as radar towers, shall have one down conductor per leg. Down conductors on all towers shall be bonded to each tower section. Down conductors shall be routed down the inside of the legs wherever practical and secured at intervals not exceeding 3 feet.

4.2.3.6.2 Pole Type Towers

Pole type towers shall be protected by at least one air terminal and have at least one down conductor. This is to provide a zone of protection for all antennas located on the tower.

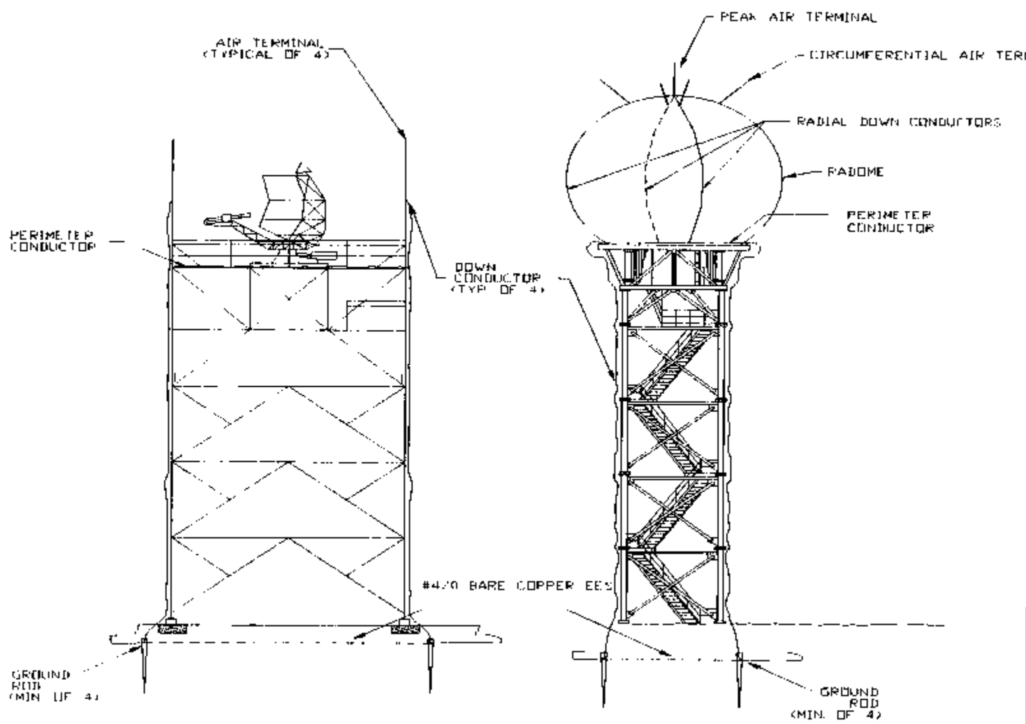
4.2.3.6.3 Towers without Radomes

Protection shall be provided for large radar antennas by extending structural members above the antenna and mounting the air terminal on top as shown in Figure V unless specifically disapproved by the Radar system OPR. Structural members shall be braced as necessary and shall not be used as part of the air terminal or down conductor. The air terminal shall be supported on the structural member and shall have a UL listed fitting on its base. The down conductor from the air terminal shall be connected to a perimeter conductor that forms a loop around the perimeter of the tower platform. Down conductors shall be run from the perimeter conductor to the EES. Each air terminal shall be provided with at least two paths to ground. All conductors shall be in accordance with NFPA 780 requirements for main conductors. All tower legs shall be bonded to the EES with a 4/0 AWG copper conductor exothermically welded at each end. This bonding conductor shall be either a separate conductor, or is permitted to be a part of the down conductor, as described in paragraph 4.2.3.4.2.

4.2.3.6.4 Radomes

Radomes shall be located within a zone of protection established according to the 100 foot radius "rolling sphere model" as described in NFPA 780. This protection can be either from air terminals mounted on the radome or air terminals or catenary wires mounted independently of the radome. When air terminals are mounted on the radome they must have two paths to the EES. A perimeter conductor shall be established at the radar antenna deck level.

Lightning protection systems for standalone radomes shall be designed and installed in consultation between the system OPR and the OPR of this document. The narrative in paragraph 4.2.3.6.5 shall be used as guidance in developing lightning protection systems for these radomes.



NOTES:

1. BOND DOWN CONDUCTORS TO EACH TOWER LEG SECTION. EXOTHERMICALLY WELD DOWN CONDUCTOR TO A 4/0 AWG COPPER CONDUCTOR ABOVE GRADE. ROUTE 4/0 CONDUCTOR THROUGH 1" PVC CONDUIT AROUND CONCRETE PIER AND 12" BELOW GRADE TO THE EES.
2. WHERE A RADOME HAS AN ELECTRICALLY CONTINUOUS FRAME, THE FRAMING MAY BE USED IN LIEU OF THE LOWER AIR TERMINALS.
3. ALL LIGHTNING PROTECTION CONNECTIONS SHALL BE FREE OF PAINT AND GALVANIZING. SCRAPE ALL STEEL FREE OF SURFACE CONTAMINANTS OR SURFACE TREATMENTS PRIOR TO MAKING EXOTHERMIC WELDS OR MECHANICAL CONNECTIONS.

Figure V. Lightning Protection for Radomes and Radar Antenna Platforms

4.2.3.6.5 Towers with Radomes

Lightning protection systems for towers with radomes shall be designed and installed in consultation between the system OPR and the OPR of this document. The narrative below shall be used as guidance in developing lightning protection systems for these structures.

Towers with radomes shall be protected with a minimum 2 foot (0.62 m) air terminal at the peak and four or more air terminals equally spaced around the circumference of the radome and oriented perpendicular to the radome. The spacing and quantity of the circumferential air terminals shall be adjusted if the antenna pattern is affected, but their sizing, position and height shall establish a protection zone as specified in 4.2.3.6.4. The circumferential air terminals shall be interconnected with main sized conductors. The radial down conductors, as indicated in Figure V, shall be connected to the air terminal on the peak. The radial down conductors shall also be connected to the perimeter conductor that forms a loop around the base of the radome.

The radial down conductors on the radome shall be routed from the air terminal at the peak of the radome, in a path following the contour of the radome, to connection with the circumferential air terminals and then to connection with the perimeter conductor as shown in Figure V. Deviations from the shortest possible path shall be allowed where near field radar analyses determine that interference from the conductors will degrade the performance of the radar. Any bends in the radial down conductors on the radome shall maintain the largest possible radii and in no case be less than 12 inches. One down conductor per leg shall connect the perimeter conductor at the base of the radome to the EES. The down conductors shall be bonded to each leg section. All tower legs shall be bonded to the EES with a 4/0 AWG copper conductor exothermically welded at each end. This bonding conductor can be the same conductor required in paragraph 4.2.3.4.2.

4.2.3.6.6 Antenna Protection
Air terminals shall be placed to protect structural towers and buildings, and antennas mounted to towers and on buildings.

4.2.3.6.7 Tower Guying
All metallic guy wire systems without insulators shall be connected to the EES with a 4/0 AWG copper conductor.

4.2.3.6.7.1 Anchors
Where multiple guy wires terminate on a single anchor, one jumper shall be allowed to connect all guy wires to the EES. The jumper shall be exothermically welded to a ground rod that is exothermically welded to the EES. Mechanically bonded jumpers of the same material and size as the guy wire shall be placed across any intermediate turnbuckles in a guy wire. On guy wires terminating in low conductivity anchors (such as concrete), a jumper of the same material and size as the guy wire shall be mechanically bonded to each guy wire above its lowest turnbuckle and bonded to the EES. All jumper connections to the guy wires shall be made with appropriate compatible connectors.

4.2.3.6.8 Waveguide, Axial Cable, and Conduit Grounding
Waveguide, axial cable, and conduit located on the tower and feeding into the facility shall be separately bonded to a ground plate mounted on the tower or directly to the EES. This bond shall be above and no greater than 2 feet (0.6 m) from the transition bend (90 degree bend) near the tower's base. Bond the ground plate to the EES with a 4/0 AWG copper conductor in accordance with the requirement in paragraph 4.2.1.6. A separate bond shall be made from the point of origin within the tower structure of each waveguide, axial cable, or conduit to the metallic tower structure. These are in addition to the bulkhead connector plate required in paragraph 4.2.1.6.

4.2.3.6.9 Staircase/Ladder Protection
The metallic access to the tower, i.e., staircase, ladder, etc., shall be exothermically bonded near its base to the EES with a 4/0 AWG copper conductor installed in a location that avoids accidental tripping or striking that could result in personnel injury. Where staircase sections, platforms etc. are not welded together, bonding jumpers shall be installed between them.

4.2.3.7 Lightning Protection for Facilities without Buildings or Antennas

Facilities such as Runway Visual Ranges are commonly built without buildings or antennas. While these are small facilities their loss can have an impact on the NAS far out of proportion to their size. These small facilities must be included within a zone of protection established with either air terminals or overhead catenary wires to prevent damage from lightning strikes.

4.2.3.8 Lightning Protection for Fences and Gates

General airport fencing is not subject to the mandates of this document. Non-FAA owned fencing, that is adjacent to FAA facilities and meets the distance criteria set out in this and sub paragraphs, shall be protected as mandated after agreement with the owner of the fencing. Fences shall be constructed using electrically conducting materials e.g., chain link fabric, metal crossbar, stranded wire, etc., using metal posts that extend a minimum of 2 feet (0.6 m) below grade into a concrete base. Metallic fence fabric with non-conductive coatings shall not be used.

A ground rod shall be installed at spacings no greater than 100 feet, and bonded to a fence post with a 4/0 AWG stranded copper conductor, exothermically welded. Install a 1 inch by $^1/_8$ inch flexible tinned copper bond strap or an insulated 4/0 AWG flexible (welding) copper conductor from any gate to the adjacent post (exothermic welding is recommended). Install the bonding strap from the gate to the post so it will not limit full motion of the gate (whether swing or slide type). Exothermically weld a 4/0 AWG bare copper conductor from the posts at each side of the gate to ground rods installed at each side of the gate. Connect the conductor to the gateposts at a height no greater than one foot above grade. Interconnect the ground rods at either side of the gate with an exothermically welded 4/0 AWG bare copper conductor buried a minimum of 18 inches below grade.

Bond across any terminations in the security wire using a short piece of the security wire material and UL listed bonding connectors. Bond the security wires to the fence posts at intervals of approximately 40 feet using a 6 AWG stranded tinned copper conductor and UL listed bonding connectors. Attach the metallic fence fabric to the fence posts with wire ties of the same material. The method of bonding fences is illustrated in Figure VII.

For gates, a horizontal bare 6 AWG stranded tinned copper conductor shall be threaded continuously through the gate fabric and mechanically bonded to the vertical gate rails.

Portions of a fence that are within 22 feet of a facility EES shall be bonded to that EES with a 4/0 AWG bare copper conductor exothermically welded to a fence post ground rod. Connections shall be made at a maximum interval of 40 feet with a minimum of two connections.

The above requirements are designed to meet the minimum National Electrical Safety Code (NESC) ANSI C2, Rule 92E.and IEEE Std 80.

Long fences, of 100 feet or greater, shall be positioned so they do not approach any part of an FAA lightning protection system closer than 50 feet if at all feasible. Grounding for portions of long fences that approach closer than 50 feet to any part of a FAA lightning protection system shall be referred to the OPR of this document.

4.2.3.8.1 Fences in High Risk Locations

NFPA 780 identifies the ability of structures to attract lightning from a significant surrounding area increasing the lightning strike frequency. For NAS facilities, the calculated high risk indices and lightning strike frequency values identify an "increased risk of strike", resultant damage, step potentials and touch potentials for adjacent areas. Consequently certain facilities require additional fence grounding for portions of the fence that fall within the combined area produced by drawing a boundary around each structure equal to 1.5 times the height of that structure in accordance with Figure VI Common Collective Area of Increased Risk. This additional fence grounding shall be in accordance with paragraph 4.2.3.8.2. This requirement applies to the following facilities.

a) Radar sites such as ASR, ARSR, TDWR, PRM.
b) ARTCC's
c) ATCT's over 100 feet in height (tall towers)
d) Large TRACON's

Grounding for fences for structures such as VOR, RTR, RCAG and lighted Navaids shall be in accordance with the site configuration design controlled by the program offices for those systems and have the approval of the OPR of this document.

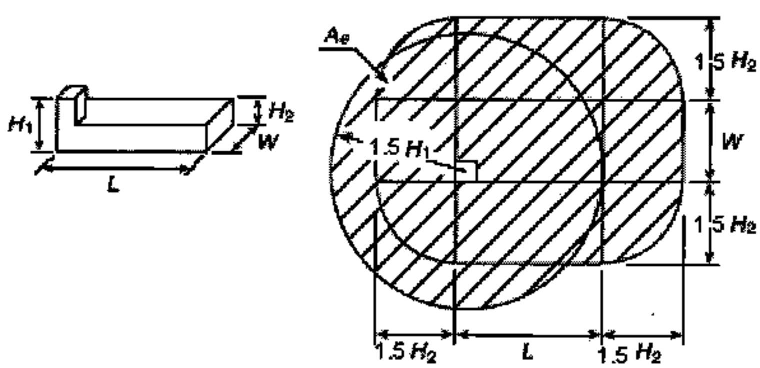


Figure VI Common Collective Area of Increased Risk

4.2.3.8.2 Fence Grounding for High Risk Locations

A buried bare 4/0 AWG stranded copper conductor (fence EES) shall be installed outside the fence where feasible (inside where not), within three feet of the fence, and two feet below grade. A horizontal bare 6 AWG stranded tinned copper conductor shall be threaded through the fencing fabric, approximately midpoint of the fence fabric, and shall be mechanically bonded to the fence posts at intervals not greater than 40 feet. A ground rod is required at these bonding locations and exothermically welded to the fence EES. The fence posts at these bonding locations shall be bonded to the fence EES with a bare 4/0 AWG stranded copper conductor, exothermically welded to the fence posts and to the ground rod. The method of bonding a fence requiring an EES is illustrated in Figure VIII.

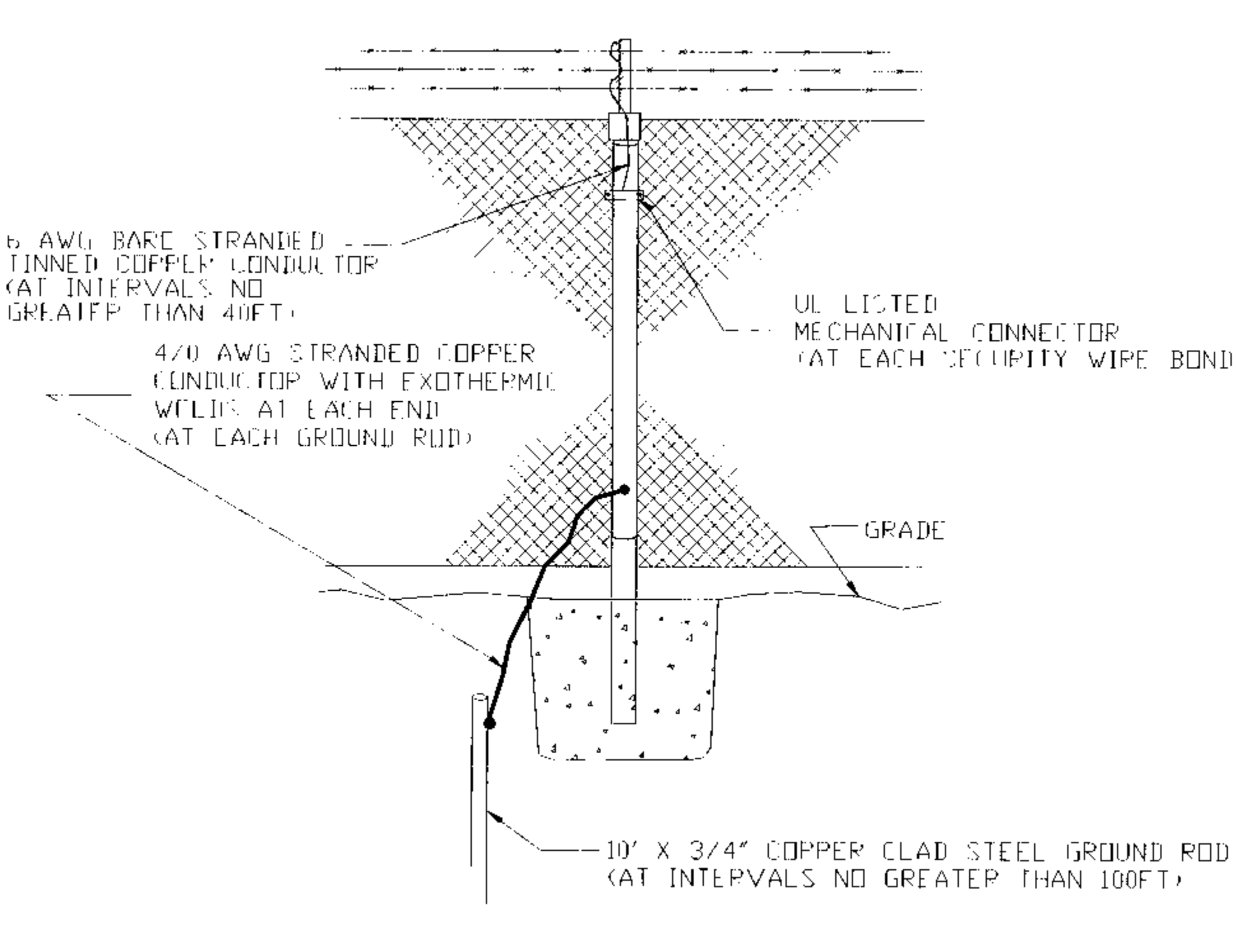


Figure VII. Fence Grounding

The fence EES shall be connected to other EES within the fence EES using buried bare 4/0 AWG stranded copper conductors. A minimum of four connections shall be installed between the fence EES and other EES for structures or buildings with an aggregate footprint of 5,000 square feet or less (preferably at the corners). A minimum of eight connections shall be installed between the fence EES and other EES for structures or buildings with an aggregate footprint greater than 5,000 square feet (preferably at the corners and at the midpoints). Aggregate footprint is defined as the sum of all building and structure footprints.

For swing gates, the horizontal bare 6 AWG stranded tinned copper conductor in the fence fabric shall continue to and be threaded through the gate fabric.

4.2.3.8.3 Fences Crossed by Overhead Power Lines

When overhead power lines cross a fence, bond a fence post on each side of the crossing to a ground rod with a bare 4/0 AWG copper conductor. These connections shall be on each side of and at least 20 feet from the overhead wire crossing. Bond the fence fabric at the top, middle and bottom of the fence and each strand of security wire placed above the fencing fabric to the grounded post with a bare 6 AWG tinned copper conductor. Where crossbars or stranded wire is used, each horizontal strand or cross bar shall be bonded to these posts. Figure VIII shows a typical fence post grounding and bonding.

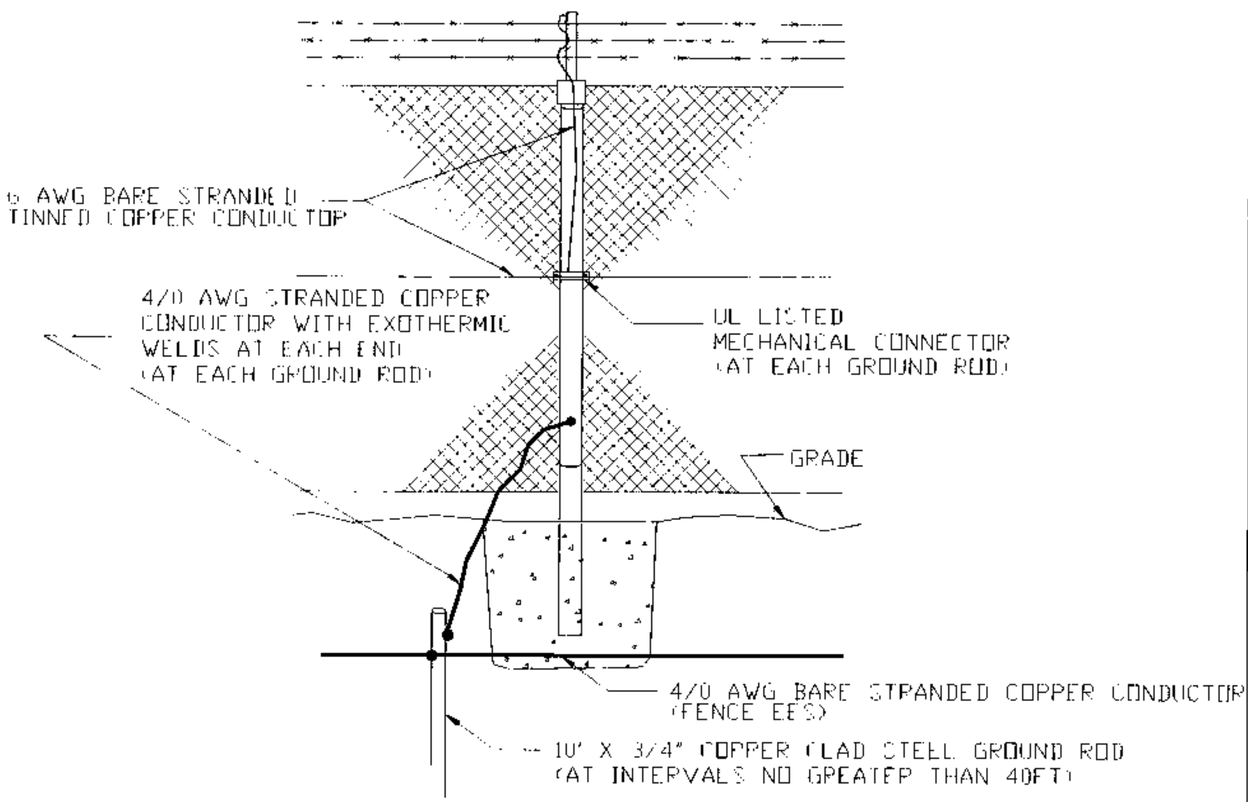


Figure VIII. Grounding Fences Requiring an EES

4.2.4 Earth Electrode System (EES) Requirements

4.2.4.1 General

An EES shall be installed at each facility. The purpose of the EES is to provide a low resistance to earth for lightning discharges, electrical and electronic equipment grounding and surge and transient protection. The EES shall be capable of dissipating within the earth the energy of direct lightning strikes with no ensuing degradation to itself. The system shall dissipate DC, AC and RF currents from equipment and facility grounding conductors.

4.2.4.2 Site Survey
A site survey shall be conducted for all sites to determine the geological and other physical characteristics. Information to be collected shall include location of rock formations, gravel deposits, soil types etc. Perform a soil resistivity test at probe spacings of 10, 20, 30 and 40 feet (3, 6, 9 and 12m) in four directions from the proposed facility. All survey data, including soil resistivity measurements, shall be noted on a scaled drawing or sketch of the site and included in the Facility Reference Data File. Additional guidance can be found in FAA Orders 6950.19 and 6950.20.

4.2.4.3 Design
The EES shall normally consist of driven ground rods, buried interconnecting conductors and connections to underground metallic pipes (not including gas lines), and tanks. The site survey required in paragraph 4.2.4.2 shall be used as the basis for the design of the EES. The design goal for the resistance to earth of the EES shall be as low as practicable and not over 10 ohms. Where conditions are encountered such as rock near the surface, shallow soils, permafrost and soils with low moisture or mineral content, after evaluation, one of the ground enhancements listed in paragraphs 4.2.4.3.1 through 4.2.4.3.4 shall be used.

4.2.4.3.1 Chemical Enhancements.
Chemical enhancements (doping) with materials such as mineral salts, Epsom salts, sulfates, etc. should only be utilized as a last resort. Chemical enhancement is dependent on soil moisture content and requires periodic (usually yearly) re-treatment and continuous monitoring to be effective. The chemicals leach into the surrounding soil and can be deposited into the water table. Typical installation is in bored holes with ground rods and in trenches.

4.2.4.3.2 Chemical Rods.
Chemical rods also require re-treatment and monitoring to ensure continuous effectiveness. Many of these systems require a drip irrigation system in dry soil conditions. Inspections must be conducted frequently for timely detection of corrosion at connection points between conductors and the chemical rod attachment point. Normal installation is insertion into the soil in accordance with manufacturer's instructions.

4.2.4.3.3 Engineered Soil Materials
Engineered soil materials are cements, soils or clays treated with a variety of materials to enhance their conductive properties. These engineered soils can be a mixture of moisture absorbing materials such as Bentonite or homogenous clays in combination with native soils and/or chemicals. Some engineered soil enhancements utilize concrete-based materials. These materials should be avoided in areas with soil movement. The concrete can break the interconnecting conductor when combined with soil movement. Engineered soil requires the presence of moisture (> 14%) to be effective. Concrete type enhancements can be very expensive. Normal installation is installation in bored holes with ground rods and in trenches.

4.2.4.3.4 Coke Breeze

Coke breeze is a material that is produced as a by-product of coke production. Coke breeze is environmentally safe, stable, and conductive even when completely dry or frozen, non-moisture dependant, compactable and very economical to install. Normal installation is in a one-foot square trench in an EES configuration with a continuous 4/0 AWG stranded copper conductor in the center of the material (see Figure IX). Placement of the trench is based on the geometry of the facility and the physical site location. Radial trenches with a center conductor can be utilized to enhance Radio Frequency (RF) ground planes in communication facilities. The top of the coke breeze trench must be covered by a minimum of one foot of native soil. Coke breeze shall contain no more than 1% sulfur by weight. Charcoal and/or petroleum-based coke breeze shall not be substituted for coke breeze derived from coal in coke ovens. Charcoal and petroleum coke typically contain high levels of sulfur, which in the presence of moisture will accelerate corrosion of the EES.

4.2.4.3.5 Ground Dissipation Plates

In shallow soil locations with limited surface space, ground dissipation plates shall be allowed in place of ground rods in the earth electrode system. The plates shall be installed at the corners of the EES at the farthest accessible point from the facility to be protected. Plates shall be constructed of a minimum one quarter-inch thick copper and be a minimum of two feet square. These plates should be installed in a vertical plane to take advantage of seasonal moisture and temperature changes in the soil. Install the plates at the same depth or deeper than the interconnecting conductor, but maintain a minimum of one-foot of native soil above the upper edge of the plate. Attachment to the EES shall be with a 4/0 AWG bare stranded copper conductor, exothermically welded to the EES and the plate. For maximum performance, the attachment point at the plate shall be at the center of the plate, not near the edge or the corners. To further enhance the effectiveness of ground dissipation plates, they shall be configured as a Jordan Dissipation Plate Design or equal as shown in Figure X. This configuration provides 2/3 more surface area at the edge than a square plate and provides multiple sharp points for increased dissipation capability. In difficult soils/areas a combination of coke breeze trenches and ground dissipation plates is highly recommended (see Figure IX and Figure X).

4.2.4.3.6 Installation of Earth Electrode Systems in Corrosive Soils

Careful consideration must be given to the installation of any grounding system in soils with corrosive elements. Two geological areas of known concern are the volcanic soils in Hawaii and Alaska. It is recommended that supplemental cathodic protection be applied to the grounding system at these locations. A buried steel plate (acting as a sacrificial anode) is connected to the EES by a 4/0 AWG stranded bare copper conductor. The 4/0 AWG conductor shall be exothermically welded to the EES and to the sacrificial plate. The conductor shall be welded to the center of the plate, not near the edge or near the corners. Minimum sizing for the sacrificial plate is four feet square (4'x4') at ½ inch thickness. In shallow soils, this would be in addition to the standard copper ground plates. For enhanced performance, plates shall be a Jordan Dissipation Plate Design or equal (see Figure X).

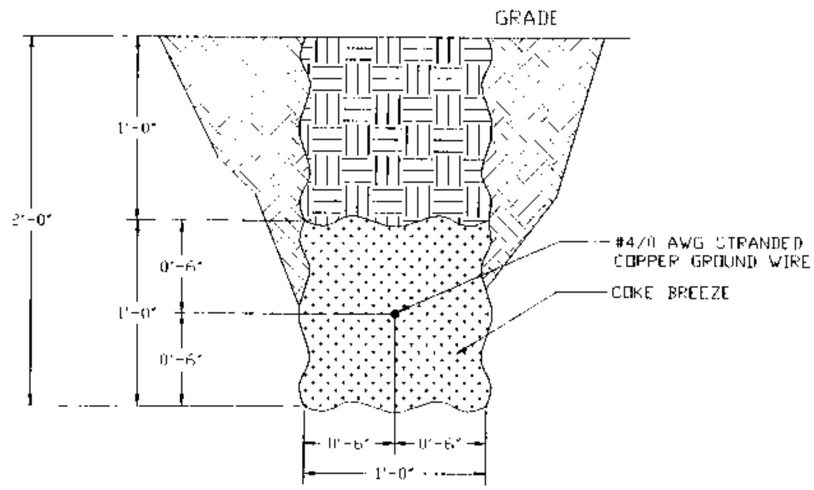


Figure IX. Grounding Trench Detail

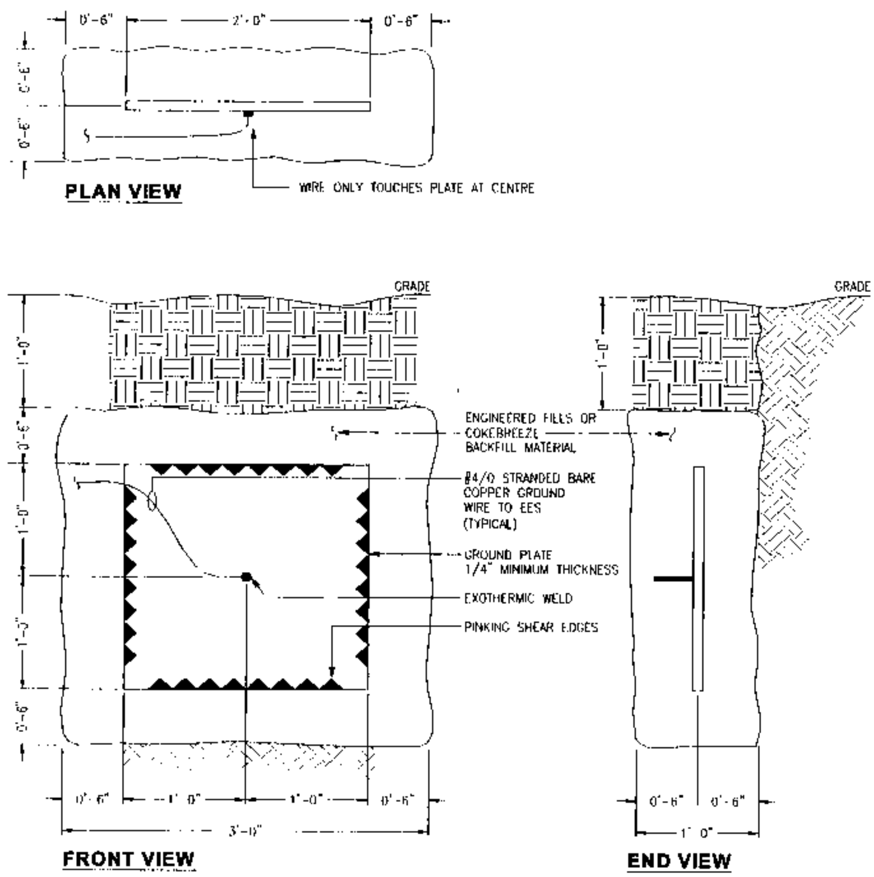


Figure X. Jordan Dissipation Plate Design

4.2.4.3.7 Configuration

The EES shall consist of at least four ground rods whose configuration and depth shall be determined by a soil test included in the site survey. At facilities that have two or more structures, e.g. a building and antenna tower, separated by 15 feet or less, a single EES surrounding both structures shall be provided. Where structures are separated by more than 15 feet but less than 30 feet, an EES shall be provided for each structure, but the EES for each structure shall be allowed to share a common side. Where the structures are separated by more than 30 feet but less than 100 feet an EES shall surround each structure and the EESs shall be interconnected by at least two buried conductors. Guidance is provided in FAA Orders 6950.19 and 6950.20.

4.2.4.3.8 Ground rods

Ground rods and their installation shall meet the following requirements:

(a) Material and Size. Ground rods shall be copper or copper clad steel, a minimum of 10 feet in length and ¾ inch in diameter. Rod cladding shall not be less than 1/100 inch thick.
(b) Spacing. Ground rods shall be as widely spaced as possible, and in no case spaced less than one-rod length. Nominal spacing between ground rods is between two and three times the rod length.
(c) Depth of Rods. Tops of ground rods shall be not less than 1foot below grade level.
(d) Location. Ground rods shall be located 2 to 6 feet outside the foundation or exterior footing of the structure. On buildings with overhangs or sidewalks in close proximity, ground rods shall be allowed at locations further out.

4.2.4.3.9 Interconnections

Ground rods shall be interconnected by a buried, bare, 4/0 AWG copper conductor. The conductor shall be buried at least 2 feet (0.6 m) below grade level. Connections to the ground rods shall be exothermically welded. The interconnecting conductor shall close on itself forming a complete loop with the ends exothermically welded. The structural steel columns of buildings shall be connected to the EES at approximately every other column at intervals not over 60 feet with a bare, 4/0 AWG stranded copper conductor. Connections shall be by exothermic welds. All underground metallic pipes, except where prohibited by the NEC (for example gas piping), and tanks (unless cathodically protected), and the telephone ground, if present, shall be connected to the EES by a copper conductor no smaller than 2 AWG. All underground, interconnecting conductors shall be bare. Exothermic welds shall not be used where hazards exist, i.e. near fuel tanks. In these cases, connections shall be accomplished with hydraulically-crimped terminations using a minimum force of 12 tons concentrically applied. The bonding resistance of all interconnections shall be one milliohm or less for each bond when measured with a 4-terminal milliohm meter.

4.2.4.3.10 Access Well

Access wells are permissible at facilities. The well should be located at a ground rod that is in an area with access to the open soil so that checks of the EES can be made once the facility is in use. The access well shall be made from clay pipe, poured concrete, or other approved wall material and shall have a removable cover. The access well shall be constructed to provide a minimum clearance (12 inches radius) from the center of the ground rod to the inside wall of the access well. The access well shall have an opening of a minimum 12 inch radius. Connections shall be by exothermic welds.

4.2.5 Main and Supplemental Ground Plates

A main ground plate shall be established as a common point of connection for all Signal Reference Structures (SRSs) for the entire facility. This main ground plate shall be connected to the EES with one 500 kcmil conductor. The conductor from the main ground plate to the EES shall be exothermically welded at the EES and shall be exothermically welded or connected with a UL listed pressure connector to the main ground plate. The main ground plate location shall be chosen to minimize conductor length, but shall not be more than 50 feet from the EES. Ground plates shall be copper and at least 12 inches (305 mm) long, 6 inches(152 mm) wide and $^1/_4$ inch (6.4 mm) thick. The main ground plate shall have a clear plastic cover that bears the caption "MAIN GROUND PLATE" in black 3/8 inch (10 mm) high letters and green slashes around the caption. The main ground plate conductor shall be color-coded green at each end.

A supplemental ground plate shall be established at the opposite side of the facility to the main ground plate and shall be color coded green/orange. This supplemental ground plate shall be used only for a second connection of the signal reference plane (SRP) and multipoint ground (MPG) systems to the EES. A large facility shall be allowed to employ more than one supplemental ground plate (contact the OPR when more than one supplemental ground plate is considered). Each supplemental ground plate or plates shall be connected to the EES with a 500 kcmil conductor. The conductor from each supplemental ground plate to the EES shall be exothermically welded at the EES and shall be exothermically welded or connected with UL listed pressure connector to the plate. The length of this conductor shall be 30% longer or shorter than the conductor between the main ground plate and the EES. Ground plates shall be copper and at least 12 inches long, 6 inches wide and $^1/_4$ inch thick. The supplemental ground plate shall have a clear plastic cover that bears the caption "SUPPLEMENTAL GROUND PLATE" in black 3/8 inch high letters and green slashes around the caption. The supplemental ground plate conductor shall be color-coded green with red tracer.

A 4/0 AWG bonding conductor shall be provided internally between the main and each supplemental ground plate and shall be color-coded green with orange tracer.

4.2.6 General Grounding and Bonding Requirements

4.2.6.1 Secure Facilities

In all areas of facilities required to maintain communications security, equipment and power systems shall be grounded in accordance with NACSIM-5203 and MIL-HDBK-232A.

4.2.6.2 Electronic Signal Return Path

The electronic signal return path shall be routed with the circuit conductor. For axial circuits, the shield serves this purpose. The electronic equipment case and SRS shall not be used as a signal return conductor.

4.2.6.3 Interior Metal Piping Systems

The interior metal piping systems shall be bonded in accordance with the NEC. An additional bond shall be required in the tower cab between the power ground system and water supply systems. Where there is a separately derived power system for the tower cab, the interior metallic piping systems near the top of the ATCT shall also be bonded to the ground plate as required in paragraph 4.2.11.2.

4.2.6.4 Electrical Supporting Structures

All metallic electrical support structures shall be electrically continuous and shall be bonded to the signal reference plane (SRP) or multipoint ground (MPG) system and to the EES.

4.2.6.4.1 Conduit

All metal conduits shall be grounded as follows:

(a) Conduit shall have a means to be bonded, prior to entering a structure, to a ground plate or bulkhead plate located outside the structure or directly to the EES. Plate(s) shall be bonded to the EES with an insulated 4/0 AWG stranded copper conductor color-coded green with a red tracer.
(b) All joints between conduit sections and between conduit, couplings, and boxes shall be electrically continuous. Surfaces shall be prepared in accordance with paragraph 4.1.1.7. Joints that are not otherwise electrically continuous shall be bonded with short jumpers of 6 AWG or larger copper conductor. The jumpers shall be welded in place or shall be attached with clamps, grounding bushings, or other devices approved for this purpose. All bonds shall be protected against corrosion in accordance with paragraph 4.1.1.8.3.
(c) Cover plates of conduit fittings, pull boxes, junction boxes, and outlet boxes shall be grounded by securely tightening all available screws.
(d) Every component of metallic conduit runs such as individual sections, couplings, line fittings, pull boxes, junction boxes and outlet boxes shall be bonded, either directly or indirectly, to the SRP or MPG system or facility steel at intervals not exceeding 50 feet.
(e) Conduit brackets and hangers shall be securely bonded to the conduit and to the metal structure to which they are attached.

4.2.6.4.2 Cable Trays and Wireways

The individual sections of all metallic support structures (cable tray systems) and wireways shall be bonded together with a minimum 6 AWG insulated copper conductor. All bonds shall be in accordance with procedures and requirements specified in paragraph 4.1.1. All cable trays shall be bonded to the SRP or MPG system within 2 feet (0.6 m) of each end of the run and at intervals not exceeding 50 feet (15 m). The resistance of each of these connections shall not exceed 5 milliohms. The minimum size bonding conductor for connection of a cable tray and wireway to the SRP or the MPG shall be 2 AWG copper conductor.

Table VIII. Grounding Conductor Color Codes

Color	Use
Solid green	NEC required grounds
Green with red and yellow tracers	Isolated grounds
Green with yellow tracer	Single point ground
Green with orange tracer	Multipoint ground
Green with red tracer	High-Energy ground

Note: Some commercial-off-the-shelf (COTS) equipment uses green with yellow tracer as a color code for equipment grounding conductors. These conductors shall be retained and grounded as required by the NEC.

4.2.6.5 Building Structural Steel Bonding Requirements

Major structural metal members internal to and about the periphery of NAS electronic equipment rooms shall be made electrically continuous by welding each joint. This shall be accomplished for all the joints of each major structural member, including welding of each roof truss to each column location. In addition, vertical columns on the periphery of the building that are bonded to the EES (paragraph 4.2.4.3.9) shall be welded as described above. Where rebar exists, it shall be connected to the EES with a minimum 2 AWG copper conductor that is applied via an exothermic weld or a hydraulically crimped termination.

In NAS electronic equipment rooms, where steel material is used in construction (including preformed decking, wall covering, etc), it shall be directly bonded (welded) to structural steel or to reinforcing bar. Where direct bonding is not practical, indirect bonds with copper conductor conforming to Table IX shall be used with a minimum of two 2 AWG conductors per 100 square feet of steel decking, wall covering etc. These connections shall be applied via an exothermic weld or a hydraulically crimped two-hole termination. All surface coatings shall be removed in accordance with paragraph 4.1.1.7. For additional installation guidance, contact the OPR of this document.

4.2.6.6 High RF Field Bonding Requirements

FAA facilities that are located in proximity to other facilities that generate high RF levels need additional shielding to protect personnel and sensitive equipment from these external RF sources. Where a determination has been made that the signal level is sufficient to cause concern the following shall be accomplished. Metal building components and attachments such as walls, roofs, floors, door and window frames, gratings and other metallic architectural features shall be directly bonded to structural steel or to reinforcing bar if structural steel is not present, in accordance with paragraph 4.1.1. Where direct bonding is not practical, indirect bonds with copper conductor conforming to Table IX shall be used. Removable or adjustable parts and objects shall be grounded with an appropriate type bond strap as specified in paragraph 4.1.1.3. All bonds shall conform to the requirements of paragraph 4.1.1. Metal building components with a maximum dimension of 3 feet (0.9 m) or less are exempt from the requirements of this paragraph as they are not efficient receiving antennas.

4.2.7 Signal Reference Structures Requirements

All FAA enclosed building facilities, used to house NAS equipment, shall be equipped with a Signal Reference Structure (SRS). Types of SRS include the following systems:

(a) Multipoint Ground (MPG) systems
   1. Conductor and plate

(b) Signal Reference Plane (SRP)
   1. Signal Reference Ground Plane (SRGP)
   2. Signal Reference Ground Grid (SRGG)

(c) Single Point Ground (SPG) systems

(d) Combination of engineered hybrid system as approved by the OPR of this document.

A SRS shall be constructed in the following areas:

a) All facility operational areas (entire room area).
b) All other areas containing electronic equipment supporting facility operations (entire room area).
c) Any area containing electrical equipment installed to address power quality (e.g., isolation transformers, power conditioning equipment, etc.) not in the same area as the operational or electronic equipment (on different floors, etc.) shall be bonded to the SRS system described above.

The above referenced operational, electronic and electrical equipment shall be bonded to the SRS installations in the area. In turn, all installed SRS's - on the same floor and on different floors - shall be bonded together. Individual areas of the SRS on a single floor shall be bonded to adjacent areas via at least two separate paths. The grounding system on each floor with electrical, electromechanical, or electronic equipment shall be bonded to adjacent floors via at least two separate paths.

The specific SRS type shall be selected by the OPR. SRS systems will be designed for the site-specific requirements of the facilities and equipment. SRS applications require the analysis of equipment bandwidth, and equipment and SRS impedances. SRS analysis will consider, among other parameters, operating frequencies and impedances, transmission line communication models for bonding wires, noise levels in low frequency analog-based equipment, and the influence of high frequency digital signal and logic equipment. SRGGs and SRGPs will be considered when recommended by a vendor. MPGs, SRGGs, and SRGPs can be constructed on ceilings, walls, or floors.

Multiple components of the facility SRS – except any SPGs – shall be bonded together with a minimum of two 4/0 AWG conductors.

All signal-carrying conductors, axial lines, and waveguides and cabling and interconnections between equipments shall be routed in immediate proximity to the SRGG or SRGP when utilized.
A typical ground system is shown in Figure XI.

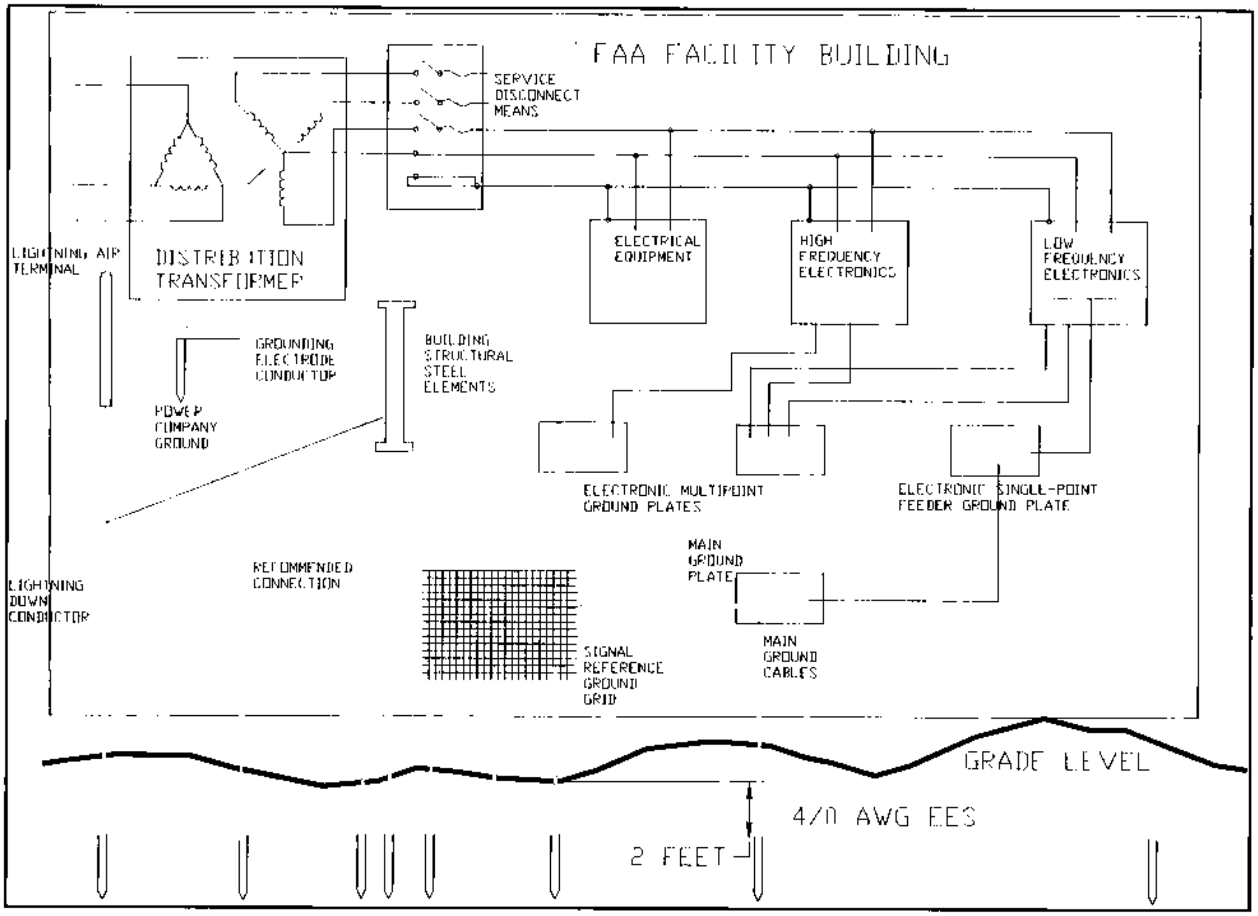


Figure XI. Facility Grounding System

Note figure colors are to distinguish systems and do not form part of a required color code

4.2.7.1 Multipoint Ground Systems

The protection of electronic equipment against potential differences and static charge buildup shall be provided by interconnecting all non-current-carrying metal objects to a multipoint ground system that is effectively connected to the EES. The multipoint ground system consists of installed network of plates and bonding jumpers, racks, frames, cabinets, conduits, wireways, cable trays enclosing electronic conductors, structural steel members, and conductors used for interconnections. The multipoint ground system shall provide multiple low impedance paths to the EES as well as between various parts of the facility, and the electronic equipment within the facility so that any point of the system has a low impedance path to the EES. This will minimize the effects of spurious currents present in the ground system due to equipment operation or malfunction, or from lightning discharges. The multipoint ground system shall not be used in lieu of the safety ground required by the NEC. The multipoint ground system is not to be used as a signal return path.

Exception: For buildings of 200 ft^2 or less, only the main ground plate is required which shall be connected to the EES with two 4/0 AWG stranded copper conductors. One of the conductors shall be 30% longer than the other. All signal grounding (single point or multipoint) shall terminate on this plate. No additional plates are required.

4.2.7.1.1 Multipoint Ground Plates and Buses

The location of the ground plate shall be chosen to facilitate the interconnection of all equipment cabinets, racks and cases within a particular area. If more than one ground plate is necessary, they shall be installed at various locations within the facility. Ground buses shall be used when distributed grounding is desired with a long row of equipment cabinets. Ground plates shall be copper and at least 12 inches long, 6 inches wide and ¼ inch thick. Ground buses shall be copper. Ground bus width and thickness shall be selected from Table IX, and shall be as long as required. Ground plates and buses shall be identified with a permanently attached plastic or metal label that is green with distinguishing bright orange slashes. The label shall bear the caption "ELECTRONIC MULTIPOINT GROUND SYSTEM" in black 3/8-inch (10 mm) high letters.

4.2.7.1.2 Ground Conductors - Plate to Plate and Plate to Bus

Conductors between plates and buses in the multipoint system shall be insulated and sized in accordance with Table IX based on the maximum path length to the farthest point in the multipoint ground system from the EES. To determine the distance to the farthest point in the multipoint system, add the length of all conductors in the multipoint system to reach the farthest plate in the system via the longest path as shown in Figure XII. Divide the sum obtained by two to obtain the maximum path length. Utilize this path length to determine the conductor size from Table IX, but in no case use a conductor smaller than 4/0 AWG. These conductors shall be color-coded green with an orange tracer or shall be clearly marked for four inches at each end and wherever exposed with a green tape overlaid with an orange tracer. Additionally, when routed in cable trays, conductors shall be color-coded every three feet. Where conductors are routed through cable trays, they shall be insulated and separated from the other conductors as far as possible. These conductors shall be insulated.

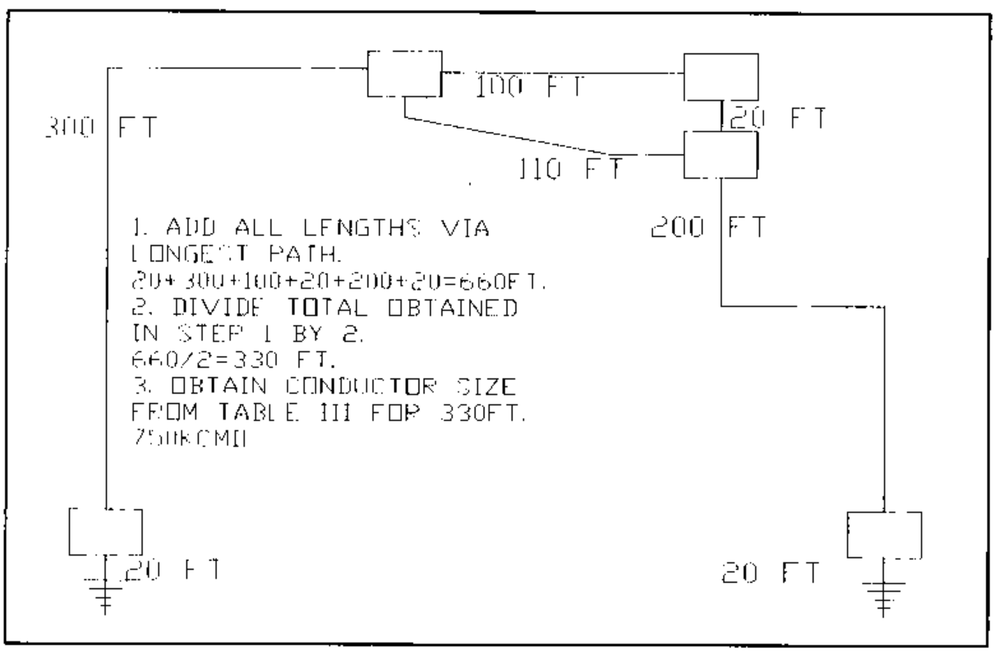


Figure XII. Multipoint Ground Conductor Size Determination

4.2.7.1.3 Ground Conductors (Plate and Bus to Equipment)

Conductors from plates and buses in the multipoint system to equipment chassis shall be sized in accordance with Table IX based on the maximum path length from the plate or bus to the equipment. These insulated conductors shall be color-coded green with an orange tracer or shall be clearly marked for 4 inches at each end and wherever exposed with a green tape overlaid with an orange tracer. Where routed through wireways, the color-coding shall be visible by opening any cover. Provide color-coding 4 inches long at intervals not exceeding 3 feet where ground conductors are routed through cable trays.

Table IX. Size of Electronic Multipoint Ground Interconnecting Conductors

Conductor Size	Max. Path Length		Bus Bar Size		Max. Path Length	
	Ft.	(m)	Inch	(mm)	Ft.	(m)
750 kcmil*	375	(114.3)	4 x 1/4	(100 x 6.4)	636	(193.9)
600 kcmil*	300	(91.4)	4 x 1/8	(100 x 3.2)	318	(96.9)
500 kcmil	250	(76.2)	3 x 1/4	(75 x 6.4)	476	(145.1)
350 kcmil	175	(53.3)	3 x 1/8	(75 x 3.2)	238	(72.5)
300 kcmil	150	(45.7)	2 x 1/4	(50 x 6.4)	318	(96.9)
250 kcmil	125	(38.1)	2 x 1/8	(50 x 3.2)	159	(48.5)
4/0 AWG	105	(32.0)	2 x 1/16	(50 x 1.6)	79	(24.1)
3/0 AWG	84	(25.6)	1 x 1/4	(25 x 6.4)	159	(48.5)
2/0 AWG	66	(20.1)	1 x 1/8	(25 x 3.2)	79	(24.1)
1/0 AWG	53	(16.2)	1 x 1/16	(25 x 1.6)	39	(11.9)
1 AWG	41	(12.5)				
2 AWG	33	(10.1)				
4 AWG	21	(6.4)				
6 AWG	13	(4.0)				

* Where these conductors are not available, parallel conductors shall be allowed, such as three 250 kcmil conductors in place of one 750 kcmil conductor, or two 300 kcmil conductors in place of one 600 kcmil conductor. The conductor sizing is based on providing a cross-sectional area of 2000 circular mils per linear foot. The bus bar sizes are chosen from available cross sections and exceed the cross-sectional requirement of 2000 circular mils per linear foot.

4.2.7.1.4 Protection

Provide mechanical protection for all conductors in the electronic multipoint ground system where they are subject to physical damage. This protection shall be provided by conduit, floor trenches, routing behind permanent structural members, or other means as applicable. Where routed through metal conduit, the conduit shall be bonded to the conductor at each end.

4.2.7.1.5 Conductor Labeling

At each multipoint grounding conductor termination the conductor shall be labeled to identify the point of termination of the other end of the conductor. This shall be accomplished by embossed label. These conductors shall also be identified every 50 feet and in junction boxes in the manner above indicating both ends.

4.2.7.2 Signal Reference Planes

Signal reference planes (SRPs) shall be constructed of either an SRGG, SRGP, or a combination of both, in accordance with the narrative below:

(a) Signal Reference Ground Grid (SRGG): A SRGG shall consist of a grid of two inch wide copper strips, 26 gauge or thicker, laid on a two feet by two feet grid, welded at each grid intersection. The SRGG shall be installed below a raised floor, at or above a dropped ceiling, or both. The perimeter of the SRGG shall extend to within six inches of the room perimeter or the edge of the raised floor (and/or dropped ceiling) area if the raised floor (and/or dropped ceiling) does not fill the entire room. The SRGG and raised floor shall be bonded together at least every six feet with bare conductors. Dropped ceiling metalwork shall be bonded to ceiling mounted SRGG using guidance provided by the OPR. A 4/0 AWG or larger bare copper conductor shall be routed around the SRGG within six inches of the grid perimeter. The copper strips of the SRGG shall be bonded to the perimeter 4/0 AWG bare copper conductor at every intersection with 4 AWG bare copper conductors. The 4/0 AWG perimeter conductor shall be bonded to the EES with a minimum of four 4/0 AWG conductors spaced as widely apart as practicable.

    Building structural steel within the perimeter of the grid and within 6 feet of the grid shall be bonded to the SRGG with a 4/0 AWG or larger conductor. All conduits, wireways, pipes, cable trays, or other metallic elements that penetrate the area shall be bonded to the SRGG where they enter the area and every 25 feet for their entire length within the area. All conduits, wireways, pipes, cable trays, or other metallic elements within 6 feet of the grid shall be bonded to the SRGG. These bonds shall be made with 4 AWG copper conductors minimum.

(b) Signal Reference Ground Plane (SRGP): All SRGP designs shall be approved by the OPR of this document. A SRGP shall consist of copper sheets, 24 gauge thickness minimum. The sheets shall be welded by any method approved by the OPR including butt, pan or lap methods. The SRGP shall be bonded to the EES with a minimum of four 4/0 AWG conductors spaced as widely as practicable.

    Building structural steel within the perimeter of the ground plane and within 6 feet of the ground plane shall be bonded to the SRGP with a 4/0 AWG or larger conductor. All conduits, wireways, pipes, cable trays, or other metallic elements that penetrate the area shall be bonded to the SRGP where they enter the area and every 25 feet for their entire length within the area. All conduits, wireways, pipes, cable trays, or other metallic elements within 6 feet of the ground plane shall be bonded to the SRGP. These bonds shall be made with 4 AWG copper conductors minimum.

All conductors and cabling shall lay on or very close (nominally, less than $\lambda/20$ of the highest system frequency) to the SRGG or SRGP. Installation of a SRGG or a SRGP shall be permitted below a raised floor, at or above a dropped ceiling, or both. Floor and ceiling portions of a

SRGG or a SRGP shall be bonded together with a minimum of four 4/0 AWG conductors spaced as widely spaced as practicable. All bonding connections between the equipment and the SRGG or SRGP shall be close-coupled, i.e., the bonding jumpers shall be as short as possible, and routed to the closest SRGG or SRGP location. When either an SRGG or an SRGP is utilized under equipment, a raised floor construction is preferred to enable routing of all connecting conductors and cabling close to the SRGG or SRGP. In this case conductors and cabling shall enter at the base of the equipment

4.2.7.3 Connection of MPG and SRP Systems to the Main and Supplemental Ground Plates

The MPG and SRP systems shall be connected to the Main and Supplemental ground plates with conductors sized in accordance with paragraph 4.2.7.1.2. Each connection shall be to the nearest MPG plate or SRP.

4.2.7.4 Connection of Electronic Enclosures to the SRS

Bonding connections to the SRS shall be allowed either to the below floor SRP or directly to the raised floor system or alternatively to an MPG as constructed in paragraph 4.2.7.1. The length of the bonding conductor shall be less than 19 inches. To prevent the possibility of problems due to resonance of a single bonding strap, two widely spaced straps of unequal length (one of the conductors shall be 30% longer or shorter than the other) shall be used to bond the equipment to the SRS. Bonding straps shall be at least 1" wide and at least 26 gauge. Bonding straps shall be in accordance with paragraph 4.1.1.3 and installed in accordance with paragraph 4.1.1.2. When necessary, any radius in the bonding connectors shall be 8 inches minimum.

4.2.8 Electronic Single Point Ground System Requirements

4.2.8.1 General

Electronic single point ground systems shall be installed in FAA facilities where required by equipment or requested by the vendor and approved by the OPR of this document. FAA facilities that do not utilize single point ground equipment are not required to install a single point ground system. The electronic single point ground system shall be isolated from the power grounding system, the lightning protection system and SRP or MPG systems (except at the main ground plate). The electronic single point ground system shall be terminated at the main ground plate or to the EES, whichever is the closest. The electronic single point ground system shall be configured to minimize conductor lengths. Conductive loops shall be avoided by maintaining a trunk and branch arrangement as shown in Figure XIII.

4.2.8.2 Ground Plates

Main, branch and feeder ground plates shall be of copper and at least 12 inches long, 6 inches wide, and ¼ inch thick. The plates shall be mounted on non-conductive material of sufficient cross section to rigidly support the plates after all conductors are connected. Bolts or other devices used to secure the plates in place shall be insulated or shall be of a non-conducting material. The plates shall be mounted in a manner that provides ready accessibility for future inspection and maintenance.

4.2.8.3 Isolation between Single Point and SRP or MPG Systems
The minimum resistance between the electronic single point ground and the SRP or MPG systems shall be 10 megohms. The resistance shall be measured after the complete network is installed and before connection to the EES or to the SRP or MPG system at the main ground plate.

4.2.8.3.1 Resistance
The maximum resistance of any bond to a ground plate shall not be greater than 1 milliohm.

4.2.8.4 Ground Conductors
All ground conductors shall be insulated copper conductors color-coded green with a yellow tracer.

4.2.8.4.1 Main Ground Conductor
When a single point ground system is established directly from the EES, the single point main ground conductor shall be an insulated 500 kcmil copper conductor not exceeding 50 feet in length. The main ground conductor shall be connected to the EES by an exothermic weld in accordance with paragraph 4.1.1.2.1.

4.2.8.4.2 Trunk and Branch Ground Conductors
An insulated trunk ground conductor shall be installed in each facility from the main ground plate to each of the branch plates as shown in Figure XIII. Insulated copper branch ground conductors shall be installed between feeder plates and branch ground plates. These conductors shall be routed to provide the shortest practical path. Trunk conductors shall be 4/0 AWG insulated copper conductors with a yellow tracer for systems where the farthest feeder plate in the system is no more than 400 feet from the EES via the conductor runs. For longer runs, select a conductor size based on providing a cross sectional area of 500 circular mils (cmil) per running foot of conductor length but in no case smaller than 250 kcmil. Trunk ground conductors shall be exothermically welded or connected with UL listed double bolted connectors to the ground plates in accordance with paragraph 4.1.1.2.4 and shall be mounted as shown on the facility drawings.

4.2.8.4.3 Electronic Equipment Ground Conductors
The conductor from the feeder ground plate (branch ground plate if there is no need for a feeder ground plate in the conductor run) to the isolated terminal or bus on the electronic equipment shall be sized at 500 cmil per running foot with a minimum size of 6 AWG.

4.2.8.5 Interconnections
All connections to the single point ground system shall be made on ground plates or buses. Split bolts and other connections to existing conductors are not allowed.

4.2.8.6 Labeling
The single point ground system shall be clearly labeled to preserve its integrity as described in the following sections.

4.2.8.6.1 Conductor Identification
At each single point grounding conductor termination the conductor shall be labeled to identify the point of termination of the other end of the conductor. This shall be accomplished by embossed label. These conductors shall also be identified every 50 feet and in junction boxes in the manner above indicating both ends.

4.2.8.6.2 Ground Plate Labeling
All ground plates shall be protected with a clear plastic protective cover spaced ¾ inch (19 mm) from the plate and extending 1 inch (25.4 mm) beyond each edge. This cover shall have a green label with distinguishing bright yellow slashes attached bearing the caption: "CAUTION, ELECTRONIC SINGLE POINT GROUND" in black $^{3}/_{8}$ inch high (10 mm) letters.

4.2.8.6.3 Protection
Provide mechanical protection for all conductors in the electronic single point ground system where they are subject to damage. This protection shall be provided by conduit, floor trenches, routing behind permanent structural members, or other means as applicable. Single point ground conductors shall be isolated from contact with any metal elements.

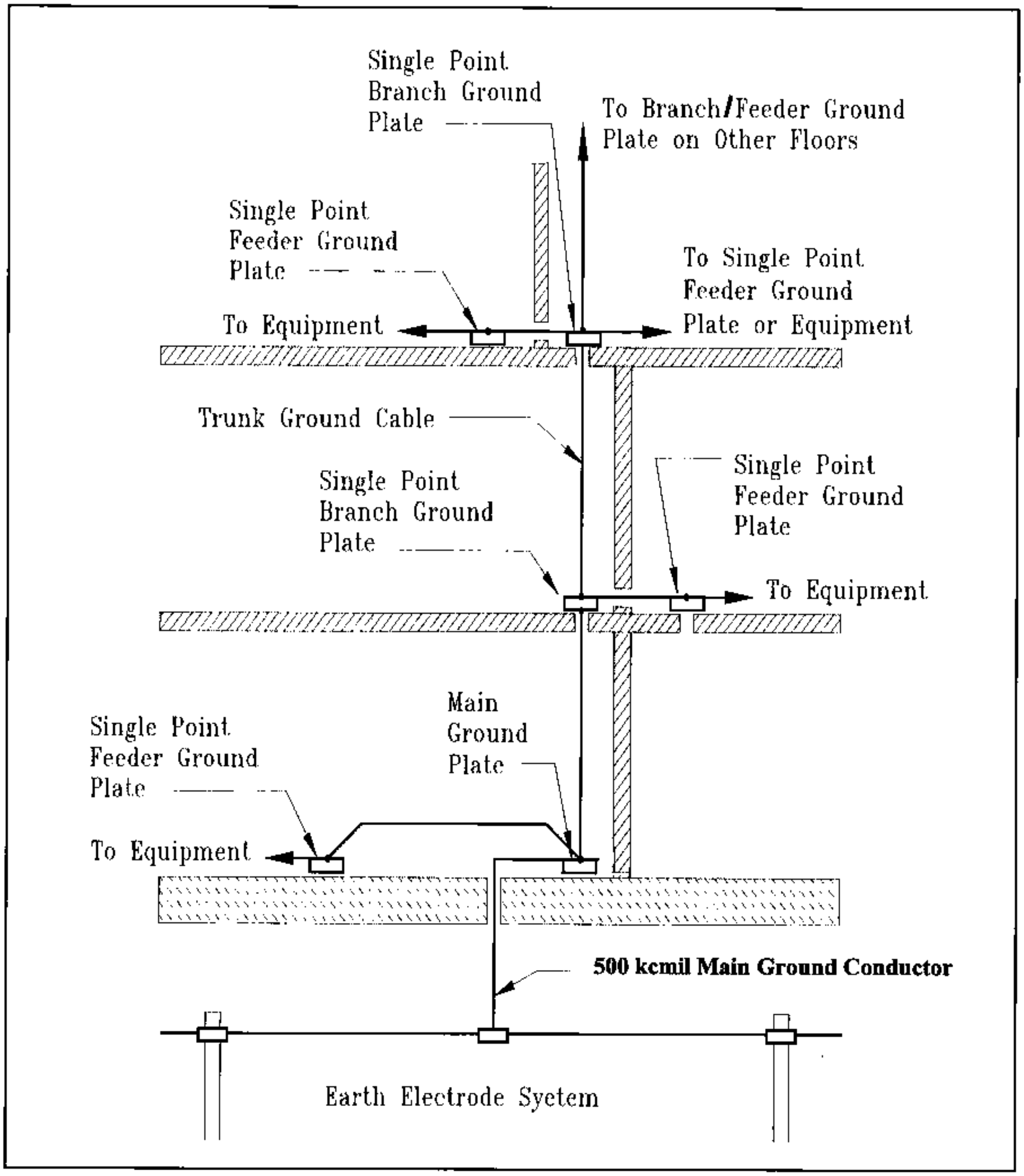


Figure XIII. Electronic Single Point Ground System Installation

4.2.9 DC Bus Grounding Requirements

Contact the OPR for specific DC Bus grounding designs.

4.2.10 National Electrical Code (NEC) Grounding Compliance

4.2.10.1 General

The facility electrical grounding shall exceed requirements of NEC Article 250 as specified herein.

4.2.10.2 Grounding Electrode Conductors

Grounding electrode conductors shall conform to the following:

(a) Facilities shall have the grounded conductor (neutral) connected to the EES by a copper grounding electrode conductor at the service disconnecting means. The grounding electrode conductor shall be sized in accordance with the NEC, but never smaller than 2 AWG.
(b) The grounding electrode conductor connection shall be made to the neutral bus in the service disconnecting means.
(c) If the grounding electrode conductor is spliced using a hydraulically crimped connector, the connector will comply with paragraph 4.1.1.2.4.4. When a grounding electrode conductor is routed through a metal enclosure, e.g., conduit, the enclosure shall be bonded at each end to the grounding electrode conductor.
(d) An equipment grounding conductor shall be routed with associated phase conductors to a second building or structure. The grounded conductor routed from the first building or structure shall not be connected to the equipment grounding conductor or EES at the second building or structure.
(e) For a separately derived system, the system bonding jumper and the grounding electrode conductor shall be located at the first downstream system disconnecting means or overcurrent device. For the grounding electrode conductor the connection shall be to the nearest effectively grounded structural metal member. Where it is not feasible to connect the grounding electrode conductor to a structural metal member, the EES shall be used. The grounding electrode conductor shall be copper and sized in accordance with NEC requirements, except that it shall not be smaller than 2 AWG.

    Separately derived systems, other than at the top of a tall ATCT, serving NAS critical and essential services shall have an additional grounding electrode conductor terminated to the EES.

4.2.10.3 Equipment Grounding Conductors

The equipment grounding conductor shall be a green-insulated wire routed in the same raceway as its' related phase and neutral conductors. Cord-connected equipment requiring an equipment ground shall include the equipment grounding conductor as an integral part of the power cord. Where power is supplied to electronic equipment through a cable and connector, the connector shall contain a pin to continue the equipment grounding conductor to the equipment chassis. Conduit or cable shields shall not be used as the equipment grounding conductor. All installations shall be in accordance with the NEC, FAA-C-1217 and with the following:

(a) Parity-sized equipment grounding conductors, same sized as the associated phase conductors, shall be used when it is recommended as good practice in a manufacturer's equipment installation requirements. Where a parity-sized equipment grounding conductor is installed it shall be bonded to bonding bushings at each end of the raceway with a bonding jumper the same size as the equipment grounding conductor. This shall be accomplished for branch circuits as a minimum.
(b) Grounding terminals in all receptacles on multioutlet assemblies shall be hardwired to an equipment grounding conductor. Strips that depend upon serrated or toothed fingers for

grounding shall not be used.

(c) All flexible metal conduits shall be provided with an external bonding jumper in addition to the internal equipment grounding conductor. The bonding jumper shall be a 6 AWG green-insulated stranded copper conductor. The bonding jumper shall terminate on fittings listed for grounding at each end of the flexible metal conduit.

(d) A seperate equipment grounding conductor shall be provided for each overcurrent device and as required by the NEC.

4.2.10.4 Color Coding of Conductors

4.2.10.4.1 Grounded Conductors

(a) Grounded conductors shall be insulated and color-coded white for 120/208V and 120/240V and gray for voltages above 120/240V. Conductors larger than 6 AWG shall be allowed to be re-identified as the grounded conductor except that green conductors shall not be re-identified.

(b) In any raceway, box, cable tray, or enclosure, where grounded conductors of different systems are present, each grounded conductor shall be identified by system, in accordance with the NEC.

(c) Color-coding of grounded conductors shall be applied at each connection and at every point where the conductor is accessible. Where routed through raceways with covers, the color coding shall be visible by removing or opening any cover. Where conductors are routed through cable trays, color coding 3 inches (75 mm) in length shall be provided at intervals not exceeding 3 feet (0.9 m).

4.2.10.4.2 Equipment Grounding Conductors

(a) Equipment grounding conductors shall be solid green in color. Insulated conductors larger than 6 AWG shall be allowed to be re-identified with green tape. White or gray conductors shall not be re-identified as equipment grounding conductors. The equipment grounding conductor from the grounding terminal of an isolated receptacle shall be color-coded green with yellow and red tracers.

(b) Color-coding of equipment grounding conductors shall be applied at each connection and at every point where the conductor is accessible. Where routed through raceways with covers, the coding shall be visible by removing or opening any cover. Where conductors are routed through cable trays, color coding 3 inches (75 mm) long shall be provided at intervals not exceeding 3 feet (0.9 m).

(c) Some COTS equipment is supplied with a green and yellow equipment grounding conductor. These conductors do not need to be replaced. These conductors shall not be connected to the single point ground system.

4.2.10.4.3 Control and DC Power Cables and Conductors

Color-coding for conductors in control cables shall be in accordance with NEMA Standard WC-5. DC power conductors, including battery cables, shall be color-coded as follows: a red for positive conductor and black for a negative conductor. The red conductor shall be marked with a positive (+) symbol and the black conductor shall be marked with a (-) symbol. The symbols shall be applied to the conductor with a shrink embossed label.

4.2.10.5 Non-Current-Carrying Metal Equipment Enclosures

(a) All non-current-carrying metal enclosures such as raceways, cable trays and panel boards shall be electrically continuous. Insulating finishes shall be removed between grounding/bonding areas of mating surfaces or bonding jumpers. Ferrous conduit (galvanized rigid metal conduit only) shall be equipped with bonding bushings at each end and the equipment grounding conductor shall be bonded to the bushings with a bonding jumper the same size as the equipment grounding conductor. This shall be accomplished in accordance with Figure XIV.
(b) Ferrous materials shall be used for enclosures, raceways, and cable trays to provide shielding from magnetic fields
(c) All battery supporting racks shall be bonded either directly to the EES or to any grounded structure with a 2 AWG conductor.

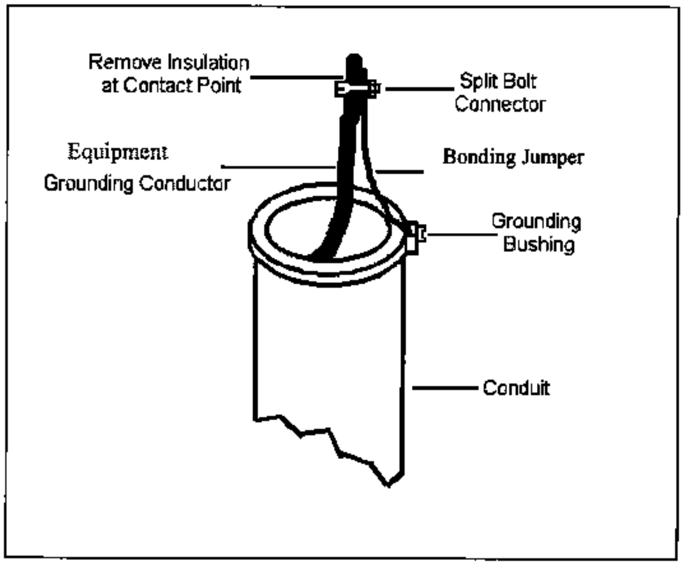


Figure XIV. Bonding of Conduit and Grounding Conductor

4.2.11 Airport Traffic Control Towers (ATCT) Special Requirements

ATCT's (Figure XV) having electronic areas in the cab, junction and sub-junction levels at the top of the shaft and also in the associated base building present a unique set of challenges for implementing lightning and transient protection. The numerous conductors running between electronic equipment located in the base building and beneath the tower cab are subject to large electromagnetic fields during a lightning strike. For this reason, special techniques shall be applied to provide an environment that minimizes the damaging effects of lightning. These techniques are mandatory for ATCT facilities with base buildings that meet the following:

(a) Over 100 feet in height to the highest point of the building, and
(b) Located in areas with a lightning flash density of 0.5/km^2/year (1.3/mile^2/year) or greater.

These techniques are recommended for application to all ATCT facilities.

4.2.11.1 General

The lightning protection, electrical, electromechanical, electronic systems, and building steel of structures shall be bonded together for safety. It is not possible for equipment near the top of the tower and at the base to have the same electrical potential during a lightning strike. It is therefore necessary to reference all systems at the top of the tower to each other and treat this area as a separate facility. SPD's shall be provided at the base building/tower shaft facility entrance and at the top of the shaft.

4.2.11.2 Main Ground Connections

In order to assure good high frequency grounding during normal operation a low impedance connection must be provided to the EES. A main ground plate shall be established on the lowest level with electrical, electromechanical, or electronic equipment serving the ATCT cab (see Figure XV). All grounding systems present at or above this level within the ATCT shall be connected to this main ground plate. A 1-foot wide 26 gauge or thicker copper strap shall connect this main ground plate to a plate at the base of the ATCT. This strap shall be routed continuously from the main ground plate to the base plate without sharp bends, loops, kinks, or splices and will provide two square feet of surface per linear foot of conductor. Substitution of a combination of conductors providing the same surface area per linear foot shall be allowed. This strap or conductors shall be mechanically bonded to the main ground plate and the base plate. The strap shall be sandwiched between the plate at each end and a 1'x1"x1/8" copper bar to insure good electrical contact and mechanical strength. Connect the base plate to the EES in an access well with two exothermically welded 500 kcmil conductors. The OPR should be consulted for assistance in meeting this requirement.

4.2.11.3 Power Distribution

All power distribution for the areas at the top of the ATCT shall be via separately derived systems. These separately derived systems shall be grounded in accordance with the requirements of NEC article 250 and paragraph 4.2.10.2(e) at the first downstream disconnecting means or overcurrent device. This point of connection is mandated to facilitate the effective installation of an SPD. An SPD, in accordance with paragraph 4.2.2.2 shall be installed on the load side of the first downstream disconnecting means or overcurrent device of each separately derived system. The ground bus at the first disconnecting means or overcurrent device shall be bonded to the main ground plate established in accordance with the requirements paragraph4.2.11.2. This connection is in addition to the grounding electrode conductor requirements of NEC article 250.

The interior metallic piping systems at the top of the ATCT shall be bonded to the main ground plate established in accordance with the requirements paragraph4.2.11.2. This connection is in addition to the bonding requirements of NEC article 250.

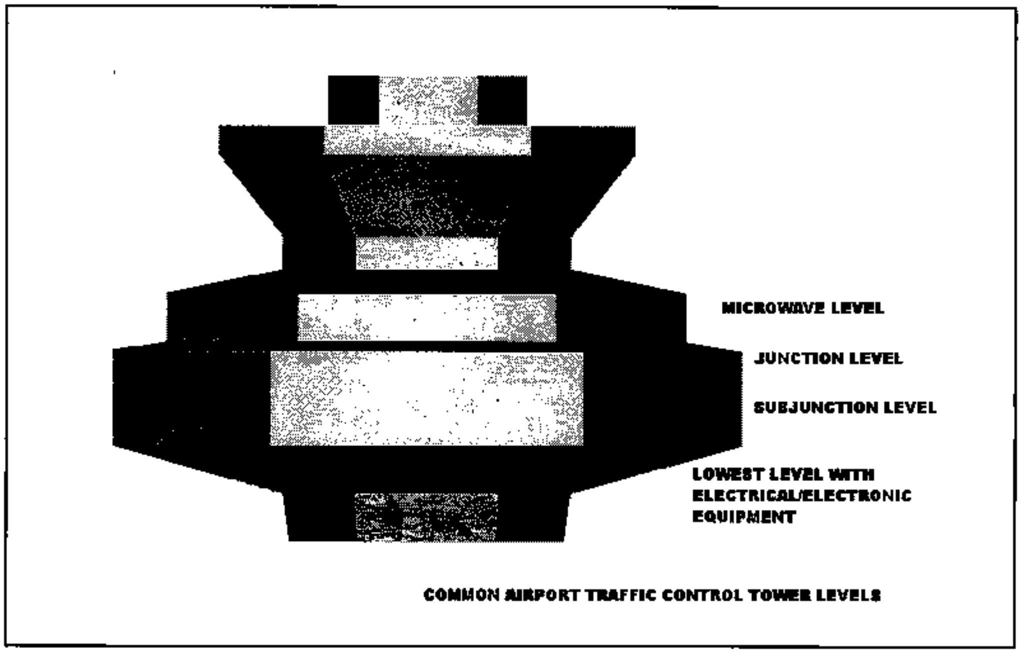


Figure XV. Airport Traffic Control Tower Levels

4.2.11.4 Bonding
Metal elements comprising the ATCT shall be bonded together and to the EES.

Provision shall be made to ensure that all rebar used in tower construction is electrically bonded together – continuous laterally and vertically to the EES – for the entire ATCT. Rebar shall be bonded to the EES with a minimum 2 AWG copper conductor that is applied via an exothermic weld or a hydraulically crimped termination.

At the top of the ATCT, the tower cab and all equipment locations supporting the cab shall be enveloped in a rudimentary Faraday cage. This shall be accomplished by bonding together all structural and fabrication steel. In turn, this steel cage shall be electrically bonded to the rebar in the concrete construction. Penetrations of the Faraday cage, e.g., conduit, water pipe, etc., shall be bonded to the cage at the point of entry. Bonding jumpers shall be a minimum 2 AWG copper conductor.

At all levels of an ATCT, horizontal metal transitions (floors, stairs, walkways, etc.) shall be bonded to structural steel and/or rebar. Elevator support structures shall be bonded to horizontal metal transitions and to the EES. All bonding jumpers shall be a minimum 2 AWG copper conductor.

If this last requirement cannot be met, contact the OPR of this document.

4.2.11.5 Signal, Communications, Axial Cables and Control Line Protection
Transient protection shall be applied at each end of vertical cables routed between the equipment room near the top of the ATCT and the associated base building. Cables between the tower cab

and equipment room areas shall be protected in accordance with paragraphs 4.2.2.5 through 4.2.2.7. Both facility and equipment levels of protection shall be provided for these lines. Enclosing metallic cabling in ferrous conduit or the use of all dielectric fiber optic cable can significantly reduce the threat of lightning related damage to ATCT and base building circuits.

4.2.11.6 Signal Reference Structure

An SRS shall be constructed in accordance with paragraph 4.2.7. This shall be accomplished for the cab and all other areas at the top of the ATCT that contain electrical, electromechanical or electronic equipment serving the cab.

4.2.11.7 Floor Coverings for Electronic Equipment and Operational Areas

Floor coverings for the cab and areas serving the cab shall be either tile or carpeting and shall be of static dissipative material. These shall be installed per manufacturers' specifications and connected to a component of the SRS – except to any single point ground system. The floor covering and installation shall meet the requirements of paragraph 4.1.3.4.8.

4.2.11.8 Single Point Grounding

Single point ground systems, if required, shall be constructed in accordance with paragraph 4.2.8. All single point ground systems and independent ground systems mandated by equipment manufacturers shall be bonded to the ATCT main ground plate established in accordance with the requirements paragraph4.2.11.2.

4.3 Equipment Requirements

Electronic equipment installed in FAA NAS facilities must comply with the requirements contained in this section.

4.3.1 Electronic Signal Lines and Cables

Electronic signal lines shall be shielded twisted pairs with an insulated covering. Cables consisting of multiple twisted pairs shall have the individual shields isolated from each other. Cables shall have an overall shield with an overall insulated covering.

4.3.1.1 Termination of Individual Shields

Termination of individual shields shall be in accordance with paragraph 4.1.2.3.2.

4.3.1.2 Termination of Overall Shields

Termination of overall shields shall be in accordance with paragraph 4.1.2.3.3.

4.3.2 Signal Control and Data Line Entrance

Procurement organizations are responsible for ensuring that electronic equipment, such as radars, navaids, or transmitters, supplied for use in FAA operational facilities, shall be provided with transient protection that reduce surges and transients to below the equipment transient susceptibility level. Signal control and data line entrance protection shall be provided as an integral part of all electronic equipment mounted internally or on the exterior of the equipment and at the facility entrance. The equipment susceptibility level is defined as the transient level on the signal, control or data lines that cause damage, degradation, or upset to electronic circuitry connected to the line. Protection for these lines is in addition to the facility protection levels specified in paragraphs 4.2.2.5 through 4.2.2.7. The procurement organizations are responsible for ensuring that testing is performed to determine voltage, current, or energy levels that will cause immediate damage to components, shorten operating life, or cause operational upset to the equipment. These tests shall consider all electrical and electronic equipment components exposed to the effects of surges or transients. The procurement organization shall ensure that facility and equipment entrance protection is coordinated to limit transients at the equipment to below the equipment susceptibility level. Requirements of this paragraph shall be included in the comprehensive control and test plans outlined in paragraph 4.1.4.2. In all cases, the following characteristics shall be evaluated.

(a) Component damage threshold. The damage threshold is the transient level that renders the component nonfunctional or operationally deficient. For solid-state components, voltage is usually the relevant parameter.
(b) Component degradation level. The component degradation level is the transient voltage or energy level that shortens the useful life of the component.
(c) Operational upset level. The operational upset level is the transient voltage or energy level that causes an unacceptable change in operating characteristics for longer than 10 milliseconds for analog equipment or a change of logic state for digital equipment.

4.3.2.1 Lines and Cables Requiring Protection

Surge protective devices shall be placed on both ends of signal, data, and control lines longer than 10 feet connecting pieces of equipment not located on and bonded to the same SRS, or when the SRGG, SRGP, and the multipoint ground system is located in different rooms or on different floors. (refer to Figure XVI). This includes all signal, data, and control lines. This equipment shall be protected as specified in paragraph 4.3.2.

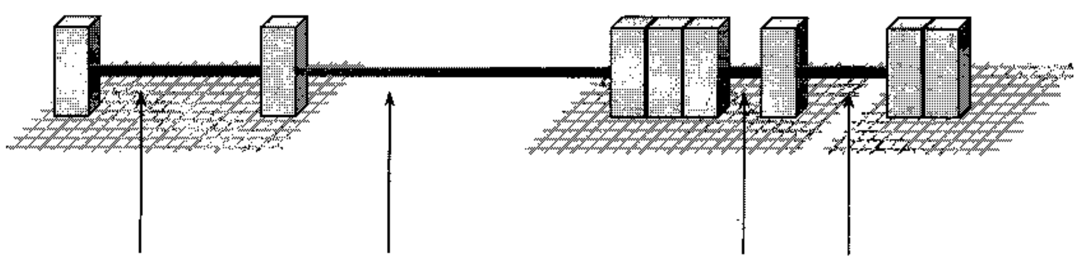


Figure XVI. Lines and Cables Requiring Protection

4.3.3 Power Entrance

Surge protective devices, components or circuits for protection of electronic equipment power lines shall be provided by the equipment manufacturer as an integral part of all electronic equipment mounted internally or on the exterior of the equipment at the cable entrance (see paragraph 4.2.2.1). These devices shall be positioned at the AC power conductor entrance to electronic equipment housed in a shielded, compartmentalized enclosure. SPDs at equipment shall provide a clamping level less than the equipment operational upset susceptibility level as defined in paragraph 4.3.2(c) and must conform to the relevant columns of Table X, Table XI, and Table XII.

(a) Maximum continuous operating voltage (MCOV). The maximum continuous operating voltage is the maximum RMS voltage an SPD will withstand at its maximum operating temperature continuously without degradation or change to any of its parameters greater than +/-10%. The MCOV will be at least 10% above the nominal system voltage. Leakage current as defined below shall not be exceeded.
(b) Leakage current. The DC leakage current will be less than 1mA for voltages at or below 1.414 x MCOV VDC.
(c) Clamp (discharge) voltage. Clamp (discharge) voltage is the maximum voltage that appears across an SPD output terminal while conducting surge currents. Clamp (discharge) voltage measured at 3kA (to ensure performance in the linear region without impacting the device lifetime performance) 8/20 microseconds shall not change more than 10% over the operating life of the Surge Protection Device as defined in Table XII. Electronic Equipment Power Entrance SPD Requirements.
(d) Overshoot voltage. Overshoot voltage shall not exceed 2 times the SPD clamp voltage for more than 10 nanoseconds. Overshoot voltage is the surge voltage level that appears across the SPD terminals before the device turns on and clamps the surge to the specified voltage level.
(e) Self-restoring capability. The SPD shall automatically return to an off state after surge dissipation when line voltage returns to normal.
(f) Operating lifetime. The SPD shall safely dissipate the number and amplitude of surges listed in Table XII.
(g) Fusing. Any fusing shall not increase the clamp voltage of the SPD and shall pass the surge current levels listed in Table XII up to the 20kA level without opening. Any fusing provided shall be coordinated with the supply fusing.

4.3.3.1 Slope Resistance

It is the purpose of this parameter to create a regime where it is possible to ensure device coordination. The slope resistance for the equipment protection shall meet the requirements of Table X and is calculated via the formula below:

$R_{slope} = (V_{10} - V_1)/9000$

Where V_{10} = the clamping voltage measured at 10kA 8/20μs
and
Where V_1 = the clamping voltage measured at 1kA 8/20μs
The values of V_{10} and V_1 used shall be measured values determined in actual testing of the SPDs and not calculated.

Table X. Equipment Power Entrance Slope Resistance Requirements

Location	Slope Resistance
Electronic equipment power entrance	60 mΩ Minimum

The voltages that must be achieved during testing at 3kA with an 8/20μs current impulse is shown in Table VI. All voltages shall be measured at the device terminals. The 8/20μs current impulse wave shape shall not lead or lag the voltage wave shape by more than 30 degrees.

Table XI. Protection Voltages at 3kA for the Equipment Power Entrance

Location	System Voltage	V_3	Limit
Electronic equipment power entrance	120/208 120/240	550 L-N, L-G 850 L-L	Minimum
Electronic equipment power entrance	277/480	850 L-N, L-G 1350 L-L	Minimum
Electronic equipment power entrance	380Delta	1350 L-L, L-G	Minimum
Electronic equipment power entrance	480 Delta	1350 L-L, L-G	Minimum

Table XII. Electronic Equipment Power Entrance SPD Requirements

Surge Current Amplitude 8/20μs Waveform	Surge Number lifetime Electronic equipment power entrance
1kA	100
10kA	25
20kA	1

Each level of surge current and the number required represents a single lifetime of an SPD.

4.3.3.2 DC Power Supply Transient Suppression

Procurement organizations are responsible for ensuring that power supplies that use 60 Hertz (Hz) power and furnish DC operating voltages to solid-state equipment used in direct support of the NAS, shall have transient suppression components from each output of the power supply to the equipment chassis. The chassis side of suppressors shall be connected as directly as possible to rectifier output ground. Operating characteristics of suppression components provided for power supply rectifier output lines shall be as follows:

(a) Operating lifetime. The transient suppressors shall safely dissipate 1000 surges with an amplitude of 200 Amps and a waveform of 1.2/50 μs. Methods of testing shall be in accordance with the guidance in IEEE C62.45.
(b) Limiting Voltage. The voltage shall be limited to a point 20% below the maximum Peak Inverse Voltage (PIV) of the DC rectifier.

4.3.3.3 Externally Mounted Electronic Equipment
When electronic equipment is not enclosed in a facility (e.g. RVR, LLWAS, OM, etc.) the power SPD protection specified in this document rated for facility entrance shall be provided. For the signal and control cables of this equipment both facility and electronic equipment entrance shall be provided at the equipment entrance as a combined protector. The grounding conductor shall be bonded to the equipment chassis and shall be of minimum length and routed to avoid sharp bends, kinks or loops. Access shall be provided for visual inspection and replacement of these SPDs.

4.3.4 Electronic Equipment Grounding

4.3.4.1 Electronic Cabinets, Racks, and Cases
All electronic cabinets, racks, and cases shall provide a grounding terminal or bus whereby a grounding jumper or wire can be mechanically connected through an electrically conductive surface to the basic frame. The metal enclosure of each individual unit or piece of electronic equipment shall be bonded to its cabinet, rack, or directly to the SRP or MPG system.

4.3.4.2 Isolated Grounding Receptacles
For reduction of electrical noise, isolated receptacles installed in accordance with the NEC shall be permitted. The isolated equipment grounding conductors used for these receptacles shall be color-coded green with red and yellow tracers at each termination, and when passing through an enclosure without termination.

4.3.4.3 Portable Equipment (with grounding conductor)
Portable electrical or electronic equipment cases, enclosures, and housings shall be considered to be adequately grounded for fault protection through the equipment grounding conductor of the power cord, provided continuity is firmly established between the case, enclosure or housing, and the receptacle ground terminal. The power cord equipment grounding conductor shall not be used for signal grounding.

4.3.4.4 AC Power Filters
All filter cases shall be directly bonded in accordance with paragraph 4.1.1.10 to the equipment case or enclosure. Filter leakage current shall not exceed 5 milliamperes (mA) per filter. Transient suppression devices, components or circuits shall be installed in accordance with paragraph 4.2.2.1.

4.3.5 Equipment Signal Grounding Requirements

4.3.5.1 Input and Output Electronic Signals

Where a common signal reference is used, low frequency analog input and output signals shall be balanced with respect to the signal reference. Extreme care shall be taken to maintain isolation between the single point ground system and the SRP or MPG system, except at the main ground plate or EES.

4.3.5.2 Multipoint Grounding of Electronic Equipment

When permitted by circuit design requirements, all internal ground references shall be directly bonded to the chassis and the equipment case. Where mounted in a rack, cabinet or enclosure, the electronic equipment case shall be bonded to the racks, cabinet or enclosure in accordance with paragraph 4.3.4.1. The DC resistance between any two points within a chassis or electronic equipment cabinet serving as ground shall be less than 25 milliohms total and not more than 2.5 milliohms per joint. Shields shall be provided as required for personnel protection and electromagnetic interference reduction.

4.3.5.2.1 Prevention of Resonance in Bonding Straps

To prevent the possibility of problems due to resonance of a single bonding strap, two widely spaced straps of unequal length shall be used to connect the equipment to the multipoint grounding bus in the equipment cabinet. Bonding shall be in accordance with the recommended practices as expressed in paragraph 4.2.7.4 and IEEE Std 1100-1999 paragraph 8.5.4.6.

4.3.5.3 Single Point Grounding of Electronic Equipment

When electronic equipment performance necessitates an isolated electronic single point ground system for proper operation, all the equipment and its installation shall comply with the following:

The single point ground system or plane shall be isolated from the electronic equipment case. If a metal chassis is used as the electronic single point ground, the chassis shall be floated relative to the case. Design practices shall be such that the single point ground of the electronic equipment can be properly interfaced with other electronic equipment without compromising the system. If necessary, this single point ground system shall be filtered for high frequencies.

4.3.5.3.1 Single Point Input and Output Signal Requirements

The "high" and "low" sides of input and output signals shall be isolated from the electronic equipment case and balanced with respect to the signal reference. Operating and adjusting controls, readouts or indicating devices, protective devices, monitoring jacks and signal connectors shall be designed to isolate both the high and low side of the signal from the case.

4.3.5.3.2 Single Point Case Isolation Requirements

The isolation between the single point ground system terminals and the case shall be 10 megohms or greater with all external power, signal and control lines disconnected from the electronic equipment.

4.3.5.3.3 Single Point Power Isolation Requirements

The isolation between the single point ground system terminals and each power conductor (including AC neutral) shall be 10 megohms or greater with the power switch in the on position and the power disconnected from the supply.

4.3.5.4 Equipment Single Point Ground Terminals

Insulated single point ground system terminal(s) shall be provided on each electronic equipment case where an isolated signal reference is required. The single point ground reference for the internal circuits shall be connected to this terminal. This terminal(s) shall be used to terminate cable shields as appropriate, and to connect the isolated signal ground of the electronic equipment to the single point ground system in the facility. A connector pin, a screw or pin on a terminal strip, an insulated stud, jack or feed through, or an insulated wire shall be an acceptable terminal so long as each terminal is clearly marked, labeled, or coded in a manner that does not interfere with its intended function. These marks, codes, or labels shall be permanently affixed and shall utilize green with yellow stripes. Wire insulation shall be green with a yellow tracer.

4.3.5.4.1 Connection of Electronic Equipment to the Single Point Ground System

Each equipment single point ground terminal shall be connected to the facility single point ground system in accordance with the following:

(a) Individual units or pieces of electronic equipment which by nature of their location or function cannot or should not be mounted with other electronic equipment, shall have an insulated copper conductor installed between the electronic single point ground terminal specified in paragraph 4.3.5.4 and the nearest electronic single point ground system ground plate. This conductor shall have a cross-sectional area of 500 circular mils per linear foot with a minimum size of 6 AWG.

(b) Where two or more units or pieces of electronic equipment are mounted together in a rack or cabinet, a single point ground bus bar shall be installed as shown in Figure XVII. The bus bar shall be copper and shall provide a minimum cross-sectional area of 125,000 circular mils (e.g., a 1inch by 1/8inch bus bar). The bus bar shall be drilled and tapped for #10 screws. The holes shall be located as required by the relative location of the isolated electronic single point grounding terminals on the electronic equipment. The bus bar shall be mounted on insulating supports that provide at least 10 megohms resistance between the bus bar and the rack or cabinet.

(c) Each electronic equipment isolated single point ground terminal shall be interconnected to the bus bar by means of a solid or flexible tinned (6 AWG minimum) copper jumper of sufficient cross sectional area so that its resistance is 5 milliohms or less. The jumper shall be insulated or mounted in a manner that maintains the required degree of isolation between the reference conductor and the enclosure. The interconnecting jumper shall be attached to the bus bar at a point nearest to the single point ground terminal to which the strap is attached. An insulated copper conductor shall be installed from the bus bar in the cabinet to the nearest electronic single point ground system. This conductor shall provide at least 500 circular mils per linear foot, and must be a minimum 6 AWG conductor.

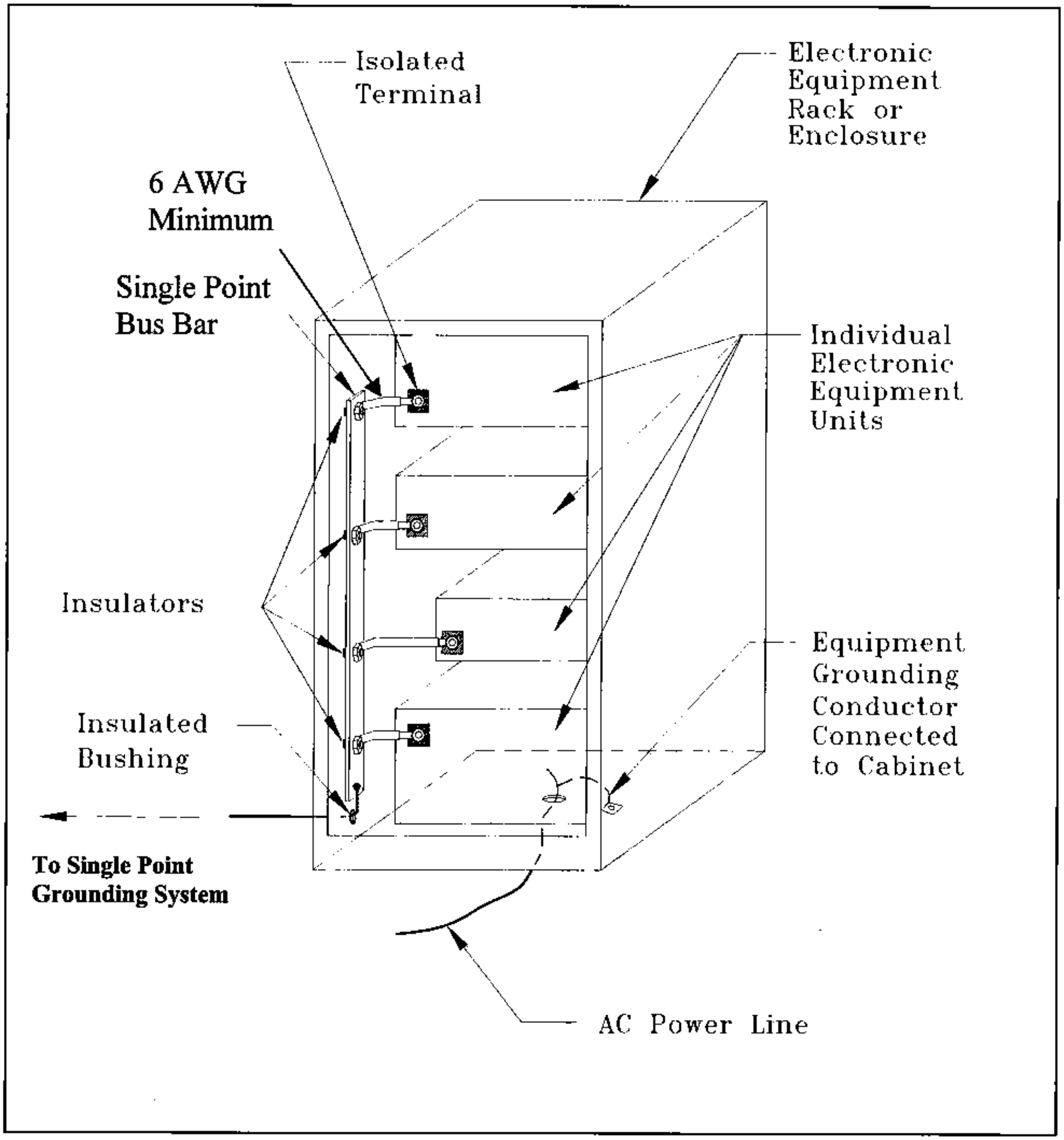


Figure XVII. Single Point Electronic Ground Bus Bar Installation in Rack or Cabinet

4.3.6 Equipment Shielding Requirements

4.3.6.1 Control of Apertures

Unnecessary apertures shall be avoided. Only those shield openings needed to achieve proper functioning and operation of the equipment shall be provided. Controls, switches, and fuse holders shall be mounted so close metal-to-metal contact is maintained between the cover housing of the devices and the case. Metal control shafts shall be grounded in accordance with paragraph 4.3.6.2. Where nonconductive control shafts are necessary, a close fitting metal sleeve peripherally bonded to the case shall be provided for the shaft. The length of the sleeve shall be no less than four times its diameter. Lights shall be filtered or shielded as needed to maintain the required degree of shielding effectiveness. Ventilation and drainage holes shall utilize appropriate shielding techniques. Care shall be taken to assure that the shielding is well bonded to the shield completely around the opening.

4.3.6.2 Metal Control Shafts

Metal control shafts shall be grounded to the equipment case through a low impedance path provided by close-fitting conductive gaskets, metal finger stock, or grounding nuts.

4.3.6.3 Shielded Compartments

Shields shall be bonded to the chassis for fault protection in accordance with paragraph 4.1.1.

4.3.7 Circuit and Equipment ESD Design Requirements

4.3.7.1 Circuit Design and Layout

The design, layout, and packaging of assemblies, circuits, and components integrated into electrical and electronic equipment shall incorporate methods and techniques to reduce susceptibility to ESD.

4.3.7.2 Component Protection

External protection shall be provided for all integrated circuits, discrete components, and other parts without internal ESD protection that are inherently susceptible to ESD. Protective components shall be installed as close as possible to the ESD susceptible item.

4.3.7.3 ESD Withstand Requirements

In the installed and operational configuration, all equipment cabinets, enclosures, racks, controls, meters, displays, test points, interfaces, etc., shall withstand a static discharge of 15,000 Volts per ESD Association Standard Test Method ESD-STM 5.1, Electrostatic Discharge Sensitivity Testing – Human Body Model (HBM). Equipment that is tested shall not suffer any operational upset or damage to any component or assembly to successfully pass ESD withstand requirements.

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5 DETAILED REQUIREMENTS

Section is not applicable to this standard.

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6 NOTES

6.1 Acronyms and Abbreviations

The following are acronyms and abbreviations used in this standard

A	Amperes	L-L	Line to Line
AC	Alternating current	L-N	Line to Neutral
ANSI	American National Standards Institute	LRU	Line replacement unit
AWG	American Wire Gauge	m	Meter
Cm	Centimeter(s)	mA	Milliampere
Cmil	Circular mils	MCM	See kcmil
DC	Direct current	MCOV	Maximum continuous operating voltage
e.g.	For example	MHz	Megahertz
EES	Earth electrode system	MPG	Electronic multipoint ground system
EMI	Electromagnetic interference	mm	Millimeter(s)
EPP	Equipotential plane	NAS	National Airspace System
EOS	Electrical overstress	NEC	National Electrical Code
ESD	Electrostatic discharge	NEMA	National Electrical Manufacturers Association
Et.al.	And others	NFPA	National Fire Protection Association
FAA	Federal Aviation Administration	No.	Number
ft.	Foot (feet)	OPR	Office of Primary Responsibility
GP	Groundable point	PVC	Polyvinyl chloride
Hz	Hertz	RF	Radio frequency
i.e.	That is	RGS	Rigid galvanized steel
in.	Inch(es)	RFI	Radio frequency interference
IEEE	Institute of Electrical and Electronics Engineers	RMM	Remote maintenance monitoring
kA	Kiloampere	SAS	Silicon avalanche diode suppressors
kcmil	Thousand circular mils	SDM	Service disconnecting means
kg	Kilogram	SPD	Surge protective device
kHz	Kilohertz	SPG	Electronic single point ground system
LAN	Local area network	SRG	Signal reference grid
LPGBS	Lightning Protection, Grounding, Bonding and Sheilding	UL	Underwriters Laboratories
"	Inch(es)	µs	Microseconds
#	Number	'	Foot (feet)
L-G	Line to Ground	V	Volts

6.2 Guidelines

Engineering design guidelines are provided for lightning protection, grounding, bonding, shielding, and transient protection in FAA Orders 6950.19 and 6950.20. Guidance for EMI protection is in MIL-HDBK-253, and for electrostatic discharge (ESD) in NFPA 77, DOD-HDBK-263, DOD-STD-1686 and IEEE1100.

6.3 Version Cross-Reference

Due to the major reorganization of FAA-STD-019e it is not feasible to provide an exact cross-reference between this standard and the previous version, FAA-STD-019d. However the handbook to FAA-STD-019e will provide information on requirements revisions and detail cost effective methods of applying them. Where possible references to the original requirements in FAA-STD-019d will be provided.